

Ecological site FX052X03X145 Panspot (Pn) Dry Shrubland

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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.

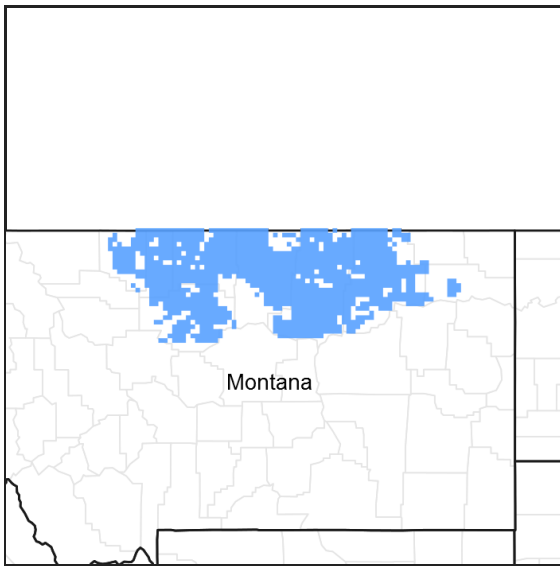


Figure 1. Mapped extent

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 sedimentary bedrock largely consisting of Cretaceous shale, sandstone, and mudstone (Vuke et al., 2007) is commonly exposed on hillslopes, particularly along drainageways. Significant alluvial deposits occur along glacial outwash channels and major drainages, including portions of the Missouri, Teton, Marias, Milk, and Frenchman Rivers. Large glacial lakes, particularly in the western half of the MLRA, deposited clayey and silty lacustrine sediments (Fullerton et al., 2013).

Much of the western portion of this MLRA was glaciated towards the end of the Wisconsin age, with the maximum glacial extent occurring approximately 20,000 years ago (Fullerton et al., 2004). The result is a geologically young

landscape that is predominantly a level till plain interspersed with lake plains and dominated by soils in the Mollisol and Vertisol orders. These soils are very productive and generally are well suited to dryland farming. Much of this area is aridic-ustic. Crop-fallow dryland wheat farming is the predominant land use. Areas of rangeland typically are on steep hillslopes along drainages.

The rangeland, much of which is native mixedgrass prairie, increases in abundance in the eastern half of the MLRA. The Wisconsin-age till in the north-central part of this area typically formed large disintegration moraines with steep slopes and numerous poorly drained potholes. A large portion of Wisconsin-age till occurring on the type of the level terrain that would typically be optimal for farming has large amounts of less-suitable sodium-affected Natrustalfs. Significant portions of Blaine, Phillips, and Valley Counties were glaciated approximately 150,000 years ago during the Illinoian age. Due to erosion and dissection of the landscape, many of these areas have steeper slopes and more exposed bedrock than areas glaciated during the Wisconsin age (Fullerton and Colton, 1986).

While much of the rangeland in the aridic-ustic portion of MLRA 52 is classified as belonging to the “dry grassland” climatic zone, sites in portions of southern MLRA 52 may belong to the “dry shrubland” climatic zone. The dry shrubland zone represents the northernmost extent of the big sagebrush (*Artemisia tridentata*) steppe on the Great Plains. Because similar soils occur in both southern and northern portions of the MLRA, it is currently hypothesized that climate is the primary driving factor affecting big sagebrush distribution in this area. However, the precise factors are not yet fully understood.

Sizeable tracts of largely unbroken rangeland in the eastern half of the MLRA and adjacent southern Saskatchewan are home to the Northern Montana population of greater sage grouse (*Centrocercus urophasianus*), and large portions of this area are considered to be a Priority Area for Conservation (PAC) by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service, 2013). This population is unique among sage grouse populations in the fact that many individuals overwinter in the big sagebrush steppe (dry shrubland) in the southern portion of the MLRA and then migrate to the northern portion of the MLRA, which lacks big sagebrush (dry grassland), to live the rest of the year (Smith, 2013).

Areas of the till plain near the Bearpaw and Highwood Mountains as well as the Sweetgrass Hills and Rocky Mountain foothills are at higher elevations, receive higher amounts of precipitation, and have a typic-ustic moisture regime. These areas have significantly more rangeland production than the drier aridic-ustic portions of the MLRA and have enough moisture to produce crops annually rather than just bi-annually, as in the drier areas. Ecological sites in this higher precipitation area are classified as the moist grassland climatic zone.

Classification relationships

NRCS Soil Geography Hierarchy

- Land Resource Region: Northern Great Plains
- Major Land Resource Area (MLRA): 052 Brown Glaciated Plains
- Climate Zone: Dry Shrubland

National Hierarchical Framework of Ecological Units (Cleland et al., 1997; McNab et al., 2007)

- Domain: Dry
- Division: Temperate Steppe
- Province: Great Plains-Palouse Dry Steppe Province 331
- Section: Northwestern Glaciated Plains 331D
- Subsection: Montana Glaciated Plains 331Dh
- Landtype Association/Landtype Phase: N/A

National Vegetation Classification Standard (Federal Geographic Data Committee, 2008)

- Class: Xeromorphic Woodland, Scrub and Herb Vegetation Class (3)
- Subclass: Cool Semi-Desert Scrub and Grassland Subclass (3.B)
- Formation: Cool Semi-Desert Scrub and Grassland Formation (3.B.1)
- Division: Cool Semi-Desert Scrub and Grassland Division (3.B.1.Ne)
- Macrogroup: *Artemisia tridentata* - *Artemisia tripartita* ssp. *tripartita* - *Purshia tridentata* Steppe and Shrubland Macrogroup (3.B.1.Ne.3)
- Group: *Artemisia tridentata* ssp. *wyomingensis* - *Artemisia tridentata* ssp. *tridentata* Steppe and Shrubland Group (3.B.1.Ne.3.a)

- Alliance: *Artemisia tridentata* ssp. *wyomingensis* Dry Steppe and Shrubland Alliance
- Association: No existing correlation

EPA Ecoregions

- Level 1: Great Plains (9)
- Level 2: West-Central Semi-Arid Prairies (9.3)
- Level 3: Northwestern Glaciated Plains (42)
- Level 4: North-Central Brown Glaciated Plains (42o) and Glaciated Northern Grasslands (42j)

Ecological site concept

This provisional ecological site occurs in the Dry Shrubland climatic zone of MLRA 52. Figure 1 illustrates the distribution of this ecological site based on current data. This map is approximate, is not intended to be definitive, and may be subject to change. Onsite evaluations are necessary, particularly in boundary or intergrade areas where ecological sites from multiple climate zones may overlap. Panspot Dry Shrubland is a somewhat extensive ecological site occurring on till plains, moraines, and fans in MLRA 52. This ecological site is especially prevalent on the Malta sublobe in Blaine and Phillips Counties where glacial till is underlain by the Bearpaw Shale Formation. This site is typically associated with Loamy, Panspot, and Thin Claypan ecological sites.

The distinguishing characteristic of this site is the presence of a dense, sodium-affected (natric) horizon at a depth of 1 inch or less from the soil surface. The natric horizon exhibits columnar structure, is very hard, and severely limits both root penetration and infiltration. Soils are typically moderately deep to very deep (greater than 20 inches to bedrock), derived from glacial till, and occur on slopes of less than 8 percent. Soil surface textures (0 to 4 inches) are very fine sandy loam to loam, and the natric horizon is clay or clay loam. Deep-rooted plant species are not well adapted to this site due to the shallow depth of the natric horizon. Species composition is dominated by shallow-rooted short-statured species. Rhizomatous species are subdominant while deep-rooted bunchgrasses are generally absent. Characteristic vegetation is blue grama (*Bouteloua gracilis*), Sandberg bluegrass (*Poa secunda*), and western wheatgrass (*Pascopyrum smithii*). The principal shrub on this site is Wyoming big sagebrush (*Artemisia tridentata* subsp. *wyomingensis*).

Associated sites

FX052X03X032	Loamy (Lo) Dry Shrubland This site occupies similar landscapes to the Panspot Dry Shrubland ecological site. In the natric soils complex, the Loamy Dry Shrubland ecological site is typically found on the highest micro-topography; whereas, the Panspot Dry Shrubland ecological site occupies the lowest positions.
FX052X03X165	Thin Claypan (Tc) Dry Shrubland This site occupies similar landscapes to the Panspot Dry Shrubland ecological site. In the natric soils complex, the Thin Claypan Dry Shrubland ecological site is typically found in mid-level micro-topography, higher than Panspot Dry Shrubland ecological site, but lower than the Claypan and the Loamy Dry Shrubland ecological sites.
FX052X03X006	Claypan (Cp) Dry Shrubland This site occupies similar landscapes to the Panspot Dry Shrubland ecological site. In the natric soils complex, the Claypan Dry Shrubland ecological site is typically found in mid-level micro-topography, higher than Panspot and Thin Claypan Dry Shrubland ecological sites, but lower than the Loamy Dry Shrubland ecological site.

Similar sites

FX052X01X145	Panspot (Pn) Dry Grassland This site differs from the Panspot Dry Shrubland ecological site in that it has slightly cooler annual temperatures and supports silver sagebrush rather than Wyoming big sagebrush.
FX052X03X032	Loamy (Lo) Dry Shrubland This site differs from the Panspot Dry Shrubland ecological site in that the root restricting layer (evidenced by columnar structure) is either absent or greater than 10 inches below the soil surface. Deep-rooted bunchgrasses are a major component of the plant community.

FX052X03X165	<p>Thin Claypan (Tcp) Dry Shrubland</p> <p>This site differs from the Panspot Dry Shrubland ecological site in that the root-restricting layer (evidenced by columnar structure) is greater than 1 inch to 4 inches below the soil surface. Deep-rooted bunchgrasses are rare or absent.</p>
FX052X03X006	<p>Claypan (Cp) Dry Shrubland</p> <p>This site differs from the Panspot Dry Shrubland ecological site in that the root-restricting layer (evidenced by columnar structure) is greater than 4 inches to 10 inches below the soil surface. Deep-rooted bunchgrasses comprise approximately 10 percent of the plant community.</p>

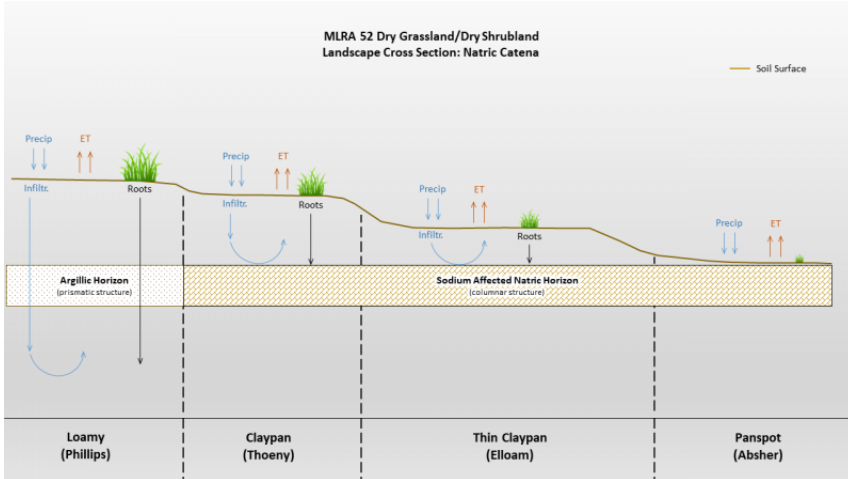


Figure 2. Figure 3. Similar and Associated Sites Diagram. Figure 3 shows an example of a landscape cross section with a natric catena.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified
Herbaceous	Not specified

Legacy ID

R052XY716MT

Physiographic features

Panspot Dry Shrubland is a common ecological site on moraines, outwash fans, and terraces. This site is moderately extensive across MLRA 52 but is most prevalent on the Malta sublobe, which stretches from southeastern Alberta and southwestern Saskatchewan through northeastern Hill, central Blaine, and southern Phillips Counties. Much of this lobe consists of an extensive ground moraine with slopes of 0 to 4 percent. The till incorporated physical and chemical properties of the underlying clayey Bearpaw Shale, which 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, because of 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 Brierly, 2011). The present-day hydrology of this site lacks a water table. As is the case with the Thin Claypan and Claypan sites, complex microrelief is normal on landforms dominated by natric soils. In relation to the Claypan and Thin Claypan ecological sites, the Panspot site is on microlows.

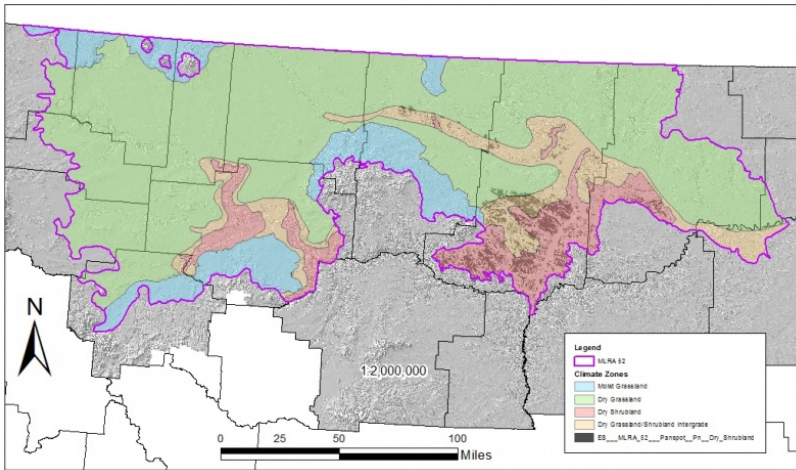


Figure 3. Figure 1. General distribution of the Panspot Dry Shrubland ecological site by map unit extent.

Table 2. Representative physiographic features

Landforms	(1) Till plain > Moraine (2) Till plain > Fan
Elevation	2,000–3,870 ft
Slope	0–8%
Aspect	Aspect is not a significant factor

Climatic features

The Brown Glaciated Plains is a semi-arid region with a temperate continental climate that is characterized by frigid winters and warm to hot summers (Cooper et al., 2001). The average frost-free period for this ecological site is 125 days. The majority of precipitation occurs as steady, soaking, frontal system rains in late spring to early summer. Summer rainfall comes mainly from convection thunderstorms that typically deliver scattered amounts of rain in intense bursts. These storms may be accompanied by damaging winds and large-diameter hail and result in flash flooding along low-order streams. Severe drought occurs on average in 2 out of 10 years. Annual precipitation ranges from 10 to 14 inches, and 70 to 80 percent of this occurs during the growing season (Cooper et al., 2001). Extreme climatic variations, especially droughts, have the greatest influence on species cover and production (Coupland, 1958, 1961; Biondini et al., 1998).

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

Table 3. Representative climatic features

Frost-free period (average)	125 days
Freeze-free period (average)	145 days
Precipitation total (average)	13 in

Climate stations used

- (1) CONTENT 3 SSE [USC00241984], Zortman, MT
- (2) FT BENTON [USC00243113], Fort Benton, MT
- (3) FT PECK PWR PLT [USC00243176], Fort Peck, MT
- (4) LOMA 1 WNW [USC00245153], Loma, MT

- (5) MALTA 7 E [USC00245338], Malta, MT
- (6) MALTA 35 S [USC00245340], Zortman, MT

Influencing water features

This site is a semi-arid upland ecological site that has a unique hydrology because very little moisture can infiltrate through the dense natric horizon, which is 1 inch or less below the soil surface. Infiltration rates on this site are approximately 0.04 inches per hour. In typical precipitation events, most of the moisture is lost through evapotranspiration before it can infiltrate. Abnormally wet years or very intense precipitation events may cause water to pond on the surface or flow laterally via surface runoff onto adjacent sites. Lateral water movement is typically limited to a localized area due to the flat topography of the landscape. The frequency and duration of ponding are not sufficient to assign this site a ponding class, and redoximorphic features are not present.

Soil features

The soil series that best represents the central concept of this ecological site is the Absher soil, which covers over 350,000 acres in MLRA 52. The Absher soil is in the Natrustalfs great group and is characterized by a surface horizon that lacks enough organic matter to have a mollic epipedon and by a dense, root-limiting, non-cemented restrictive layer 1 inch or less 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 Absher soil is in the fine family and has smectitic mineralogy. Clayey till (28 to 42 percent clay) is the typical parent material for this series, but the Panspot Dry Shrubland ecological site may also occur on soils derived from glaciofluvial deposits. The soil moisture regime for 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 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 50 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 olive brown (2.5Y 4/3) to very dark grayish brown (2.5Y 3/2). The surface horizon of these soils does not typically react with hydrochloric acid. Depth to secondary carbonates and soluble sulfate salts is typically about 5 inches below the soil surface. Calcium carbonate equivalent is typically less than 5 percent in the upper 5 inches and less than 10 percent in lower horizons. In the upper 20 inches, electrical conductivity is at some point more than 4 but less than 16 and the sodium absorption ratio is typically less than 15. These salts lower the amount of plant-available water. Soil pH classes are moderately acid to slightly alkaline in the surface horizon and neutral to strongly alkaline in the subsurface horizons. The soil depth class for this site can be moderately deep (between 20 and 40 inches to bedrock) 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 is typically less than 15 percent. Some areas, particularly in some areas of Phillips and Valley counties, can have more than 35 percent gravel on the surface.

Table 4. Representative soil features

Parent material	(1) Till (2) Glaciolacustrine deposits
Surface texture	(1) Loam (2) Fine sandy loam (3) Silty clay loam
Drainage class	Well drained
Depth to restrictive layer	0–1 in
Soil depth	20–72 in
Available water capacity (0–40in)	2.9–3.4 in
Calcium carbonate equivalent (0–5in)	0–4%

Electrical conductivity (0-20in)	4–15 mmhos/cm
Sodium adsorption ratio (0-20in)	0–14
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) (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 Panspot Dry Shrubland provisional ecological site in MLRA 52 consists of four states: The Reference State (1), the Altered State (2), the Cropland State (3), and the Post-Cropland State (4). Plant communities associated with the Panspot Dry Shrubland 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 (*Uroditellus* spp.) also influenced this plant community (Salo et al., 2004). Grasshoppers and periodic outbreaks of Rocky Mountain locusts (*Melanoplus spretus*) also played an important role in the ecology of these communities (Lockwood, 2004).

Fire is a critical dynamic in the Dry Shrubland climate zone, although fire frequency and intensity are much less on the Panspot Dry Shrubland ecological site than on other, more productive sites. The historic ecosystem experienced periodic lightning-caused fires. 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). It is difficult to precisely determine the fire return interval in the Dry Shrubland climate zone, but estimates range from 6 to 25 years (Bragg, 1995) to 10 to 70 years (Howard, 1999).

Generally, the herbaceous vegetation is resilient to fire and the primary effects of fire are reduction of litter and short-term fluctuations in production (Vermeire et al., 2011, 2014). However, studies have shown that very short fire return intervals (less than 5 years) can have a negative effect, shifting species composition toward warm-season, short-statured grasses (Shay et al., 2001; Smith and McDermid, 2014). Conversely, fire has a significant effect on Wyoming big sagebrush cover. Wyoming big sagebrush is a non-sprouting shrub and is most often killed by fire (Howard, 1999). Often, it may take 30 years or more for a stand to recover following fire (Watts and Wambolt, 1996; Wambolt et al., 2001). It is likely that fire return intervals shorter than 30 years will result in a reduction in Wyoming big sagebrush cover over the long term. Long-term fire suppression in the 20th century removed periodic fire from the ecosystem altogether. Very little is known how this has affected the Dry Shrubland ecosystem. Some studies suggest an increase in Wyoming big sagebrush cover, presumably due to fire suppression (Bloom-Cornelius, 2011). Increased decadence in Wyoming big sagebrush may also occur (Howard, 1999), but these results are inconclusive.

Lack of periodic fires can also result in an increase in litter accumulation and, in some cases, provide ideal conditions for seed germination and seedling establishment of non-native annual brome species, such as field brome or Japanese brome (*Bromus japonicus*) (Whisenant, 1990). These species have become naturalized in

relatively undisturbed grasslands (Ogle et al., 2003; Harmony, 2007) and can be present in any state within the scope of this ecological site. They typically do not have a significant ecological impact; however, their presence can reduce the production of cool-season perennial grasses in some cases (Haferkamp et al., 1997). Their abundance varies depending on precipitation and germination conditions. The fire-recovery cycle is a critical element in managing the Dry Shrubland ecosystem. Further study is needed in this area to determine a balanced and sustainable fire cycle.

Drought or improper grazing of this site can result in a reduction in the cover of the perennial grasses and an increase in bare ground, cactus, and annual species. 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 site due to improper grazing can result in a community dominated by cactus and annual forbs. Non-native annual brome grasses may become common in this state. It is hypothesized that annual bromes may at some point dominate the ecological dynamics of this site and result in an invaded state. However, this phenomenon has not been sufficiently documented and the ecological mechanisms are unclear. Further investigation of invasive species dynamics is needed prior to incorporating an invaded state into the state-and-transition model (STM).

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 with introduced species. Sites left to undergo natural plant succession after cultivation are unlikely to return to the Reference State (1) in a reasonable amount of time. Even much more productive sites may take several decades before they can support native vegetation similar to the Reference State (1) (Christian and Wilson, 1999). The Panspot Dry Shrubland ecological site is likely to take much longer due to the unfavorable physical and chemical soil properties. Natric chemical properties near the soil surface tend to cause these soils to crust following cultivation, therefore making it difficult for vegetation to reestablish naturally. Reestablishment of perennial vegetation may be more successful if the site is reseeded; however, studies have not been conducted on this site specifically. On more productive ecological sites, non-native seedings, particularly crested wheatgrass, may persist indefinitely (Christian and Wilson, 1999). Stand vigor is expected to be less on the Panspot Dry Shrubland ecological site, but stand longevity is unknown at the time of this writing. 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 can invade relatively undisturbed grasslands (Heidinga and Wilson, 2002; Henderson and Naeth, 2005), but its invasion has not been documented on the Panspot Dry Shrubland ecological site. It is hypothesized that the inhospitable nature of the soil makes it extremely difficult for invasive perennials to establish on the site.

The state-and-transition model (STM) diagram (Figure 2) suggests possible pathways that plant communities on this site may follow as a result of a given set of ecological processes and management. The site may also support states not displayed in the STM diagram. Landowners and land managers should seek guidance from local professionals before prescribing a particular management or treatment scenario. Plant community responses vary across this MLRA due to variability in weather, soils, and aspect. The reference community phase may not necessarily be the management goal. The lists of plant species and species composition values are provisional and are not intended to cover the full range of conditions, species, and responses for the site. Species composition by dry weight is provided when available and is considered provisional based on the sources identified in the narratives associated with each community phase.

State 1: Reference State

The Reference State (1) contains three community phases characterized by shortgrasses, mid-statured, rhizomatous wheatgrasses, and Wyoming big sagebrush, a perennial, evergreen, non-sprouting shrub. This state evolved under the combined influences of climate, grazing, and fire with climatic variation having the greatest influence on cover and production. In general, this state was resilient to grazing, although heavy grazing could influence species composition in localized areas. Due to sparse vegetation, fire intensity is low and effects are generally limited to a reduction of Wyoming big sagebrush cover.

Phase 1.1: Shrubland Community Phase

The Shrubland Community Phase (1.1) is dominated by shortgrasses, western wheatgrass, and Wyoming big sagebrush. The most dominant short-statured species appear to be blue grama and needleleaf sedge (*Carex duriuscula*). Prairie Junegrass (*Koeleria macrantha*) may be present on more productive areas. Thickspike wheatgrass (*Elymus lanceolatus*) can occur on this site, but western wheatgrass tends to be predominant, due to its greater tolerance of higher temperatures and droughty conditions (Coupland, 1961; Cooper et al., 2001; Heidel et al., 2000). Common forbs are woolly plantain (*Plantago patagonica*) and pepperweed (*Lepidium* spp.). Shrubs and subshrubs include prairie sagewort (*Artemisia frigida*) and winterfat (*Krascheninnikovia lanata*). Plains pricklypear (*Opuntia polyacantha*) commonly occurs at 10 percent composition or less in this phase. The principle shrub on this site is Wyoming big sagebrush, canopy cover is approximately 1 to 5 percent. The approximate species composition of the reference plant community is as follows:

Percent composition by weight*

Rhizomatous Wheatgrass 25%
Blue Grama 15%
Sandberg Bluegrass 5%
Sedge spp. 5%
Other Native Graminoids 20%
Native Forbs 5%
Wyoming big sagebrush 5-10% (canopy cover 1-5%)
Other shrubs/subshrubs 5-10%
Plains Pricklypear 10%

Estimated Total Annual Production (lbs./ac)*

Low - 50
Representative Value - 150
High - 300

Average Shrub Height (inches)*

Low - 2
Representative Value - 5
High - 9

*Estimated based on current data – subject to revision

Phase 1.2: Post-Fire Community Phase

The Post-Fire Community Phase (1.2) occurs when the plant community is burned either by wildfire or prescribed fire and may persist for as long as 30 years after burning. It is characterized by a shortgrass-rhizomatous wheatgrass plant community. The predominant short-statured species are blue grama and needleleaf sedge. Other species that occur in this phase include prairie Junegrass and Sandberg bluegrass. Total cover of shortgrasses is similar to the Shrubland Community Phase (1.1). Western wheatgrass is the primary rhizomatous species, although thickspike wheatgrass may also occur. Common forbs are woolly plantain (*Plantago patagonica*) and pepperweed (*Lepidium* spp.). Plains pricklypear (*Opuntia polyacantha*) commonly occurs at low cover in this phase. Fire intensity on this ecological site is typically low, however, in this phase, it is still sufficient to significantly reduce cover of Wyoming big sagebrush. Recovery of Wyoming big sagebrush following fire depends on many factors including climate, proximity to a seed source, and fire intensity. Typically, there is little or no regeneration for 5 to 10 years post-fire, then cover begins to increase gradually until an equilibrium level is reached (Watts and Wambolt, 1996). Generally recovery is prolonged, sometimes taking as long as 30 years (Wambolt et al., 2001).

Phase 1.3: Shortgrass Community Phase

The Shortgrass Community Phase (1.3) occurs when site condition declines due to drought or improper grazing management. This community phase is characterized by an increase in shortgrasses, particularly blue grama, and the elimination or near elimination of rhizomatous wheatgrasses. Plains prickly pear and annual forbs, such as woolly plantain, also increase in this phase. The amount of bare ground also begins to increase. As a result, the site is subject to increased erosion and the soil is exposed to increase solar heating. Cover of Wyoming big sagebrush will vary depending on the length of time since the last burn.

Community Phase Pathway 1.1a

Fire will transition the Shrubland Community Phase (1.1) to the Post-Fire Community Phase (1.2). Wyoming big sagebrush is killed and perennial grasses will dominate the site.

Community Phase Pathway 1.1b

Drought, improper grazing management, or a combination of these factors can shift the Shrubland Community Phase (1.1) to the Shortgrass Community Phase (1.3). These factors favor an increase in blue grama and a decrease in rhizomatous wheatgrasses (Adams et al., 2013; Coupland, 1961). Wyoming big sagebrush cover will be similar to the Shrubland Community Phase (1.1).

Community Phase Pathway 1.2a

Thirty years or more of natural vegetative regrowth will transition the Post-Fire Community Phase (1.2) to the Shrubland Community phase (1.1). Thirty years or more without fire permits Wyoming big sagebrush to recolonize the site.

Community Phase Pathway 1.2b

Drought, improper grazing management, or a combination of these factors can shift the Post-Fire Community Phase (1.2) to the Shortgrass Community Phase (1.3). These factors favor an increase in blue grama and a decrease in rhizomatous wheatgrasses (Adams et al., 2013; Coupland, 1961). Wyoming big sagebrush cover will be similar to the Post-Fire Community Phase (1.2).

Community Phase Pathway 1.3a

Less than 30 years post-fire; normal or above-average precipitation and proper grazing management transitions the Shortgrass Community Phase (1.3) to the Post-Fire Community Phase (1.2).

Community Phase Pathway 1.3b

Thirty years or more post-fire; normal or above-average precipitation and proper grazing management transitions the Shortgrass Community Phase (1.3) to the Shrubland Community Phase (1.1).

Transition T1A

Prolonged drought, improper grazing practices, or a combination of these factors weaken the resilience of the Reference State (1) and drive its transition to the Altered State (2). The Reference State (1) transitions to the Altered State (2) when perennial grasses become rare and contribute little to production. Plains pricklypear and annual forbs dominate the plant community.

Transition T1B

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 (3).

State 2: Altered State

The Altered State (2) consists of two community phases. This state occurs due to long-term drought, improper grazing management, or a combination of these factors. The dynamics of this state are not well understood. This state has a high amount of bare ground. It is hypothesized that this results in increased heating of the soil by solar radiation. The increased heating exacerbates the already dry site conditions and creates a self-perpetuating condition of extreme drought. These extremely dry and hot conditions make it very difficult for perennial species to persist or establish. This hypothesis has not been tested and requires further investigation. Non-native annual bromes are also known to persist in this state. Preliminary observation indicates that their abundance is highly variable and dependent on precipitation patterns and fall germination conditions. It is not known if the brome grasses alter the site properties sufficiently to transition it to an Invaded State (3). Cover of Wyoming big sagebrush varies depending on the length of time since the last fire, but fire is not believed to be a significant factor within this state because vegetative cover is insufficient to carry it.

Phase 2.1: Shrub/Cactus Community Phase

The Shrub/Cactus Community Phase (2.1) occurs when site conditions decline due to long-term drought or improper grazing, and a fire has not occurred on the site for at least 30 years. In this phase, perennial grasses, such as blue grama, and rhizomatous wheatgrasses have been largely eliminated and replaced by plains pricklypear and annual forbs, such as woolly plantain. The amount of bare ground is high, and the soil is exposed to erosion and solar heating. Cover of Wyoming big sagebrush is 1 to 5 percent.

Phase 2.2: Cactus/Annual Forb Community Phase

The Cactus/Annual Forb Community Phase (2.2) occurs when site conditions decline due to long-term drought or

improper grazing, and a fire has occurred on the site less than 30 years prior. In this phase, perennial grasses, such as blue grama, and rhizomatous wheatgrasses have been largely eliminated and replaced by plains pricklypear and annual forbs, such as woolly plantain. The amount of bare ground is high, and the soil is exposed to erosion and solar heating. Wyoming big sagebrush is rare.

Transition T2A

Tillage or application of herbicide followed by seeding of cultivated crops, such as winter wheat, spring wheat, and barley, transitions the Altered State (2) to the Cropland State (3).

Restoration Pathway R2A

It is hypothesized that solar heating creates a self-perpetuating condition of extreme drought that suppresses establishment of perennial species. A reduction in livestock grazing pressure alone may not be sufficient to restore the Altered State (2) to the Reference State (1). Intensive management treatments may be necessary (Hart et al., 1985). However, it is not known how well this site responds to practices such as mechanical treatment of grazing land and range seeding. Therefore, returning the Altered State (2) to the Reference State (1) will likely require considerable energy and cost and may not be feasible within a reasonable amount of time.

State 3: Cropland State

The Cropland State (3) occurs when land is put into cultivation. Major crops in MLRA 52 include winter wheat, spring wheat, and barley.

Transition T3A

The transition from the Cropland State (3) to the Post-Cropland State (4) occurs with the cessation of cultivation. The site may also be seeded to perennial forage species, such as introduced grasses/legumes, or a mix of native species.

State 4: Post-Cropland State

The Post-Cropland State (4) 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 (3) if the site is put back into cultivation. No formal studies have been obtained regarding Wyoming big sagebrush recovery following cultivation. Further investigation is needed to assess Wyoming big sagebrush recovery in the Post-Cropland State (4).

Phase 4.1: Abandoned Cropland Community Phase

The Abandoned Cropland Community Phase (4.1) occurs when cropland is abandoned. In the absence of active management, the site can re-vegetate naturally and, over time, potentially return to a perennial grassland community with Sandberg bluegrass and blue grama. The chemical properties of the soil surface layers tend to cause crusting on this site following cultivation. As a result, revegetation is likely to take much longer on this site than on a more favorable site, such as Loamy. The first species to establish after cropland is abandoned are typically annual and biennial forbs and annual brome grasses (Samuel and Hart, 1994). At this point, the site is extremely susceptible to erosion due to the absence of perennial species. Eventually, these pioneering annual species are replaced by perennial forbs and perennial shortgrasses, such as blue grama. Due to tillage breaking up the dense soil structure, it may be possible for perennial bunchgrasses, such as needle and thread, to return; however, this has not been fully evaluated on this site. 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 4.2: Perennial Grass Community Phase

In the Perennial Grass Community Phase (4.2) reestablishment of perennial vegetation may be more successful if the site is reseeded; however, studies have not been conducted on this site specifically. More favorable sites seeded to perennial forage species, particularly introduced perennial grasses, can persist for several decades. Monocultures of crested wheatgrass can persist for at least 60 years (Krzic et al., 2000; Henderson and Naeth, 2005). A mixture of native species may also be seeded. It is possible that tillage operations may have broken up the

dense soil structure enough that the Perennial Grass Community Phase (4.2) is more productive than the Reference State (1), but specific data has not been collected. Chemical soil properties would likely still reduce stand vigor and production on this site compared to a Loamy ecological site.

Transition 4A

Tillage or application of herbicide followed by seeding of cultivated crops, such as winter wheat, spring wheat, and barley, transitions the Post-Cropland State (4) to the Cropland State (3).

State and transition model

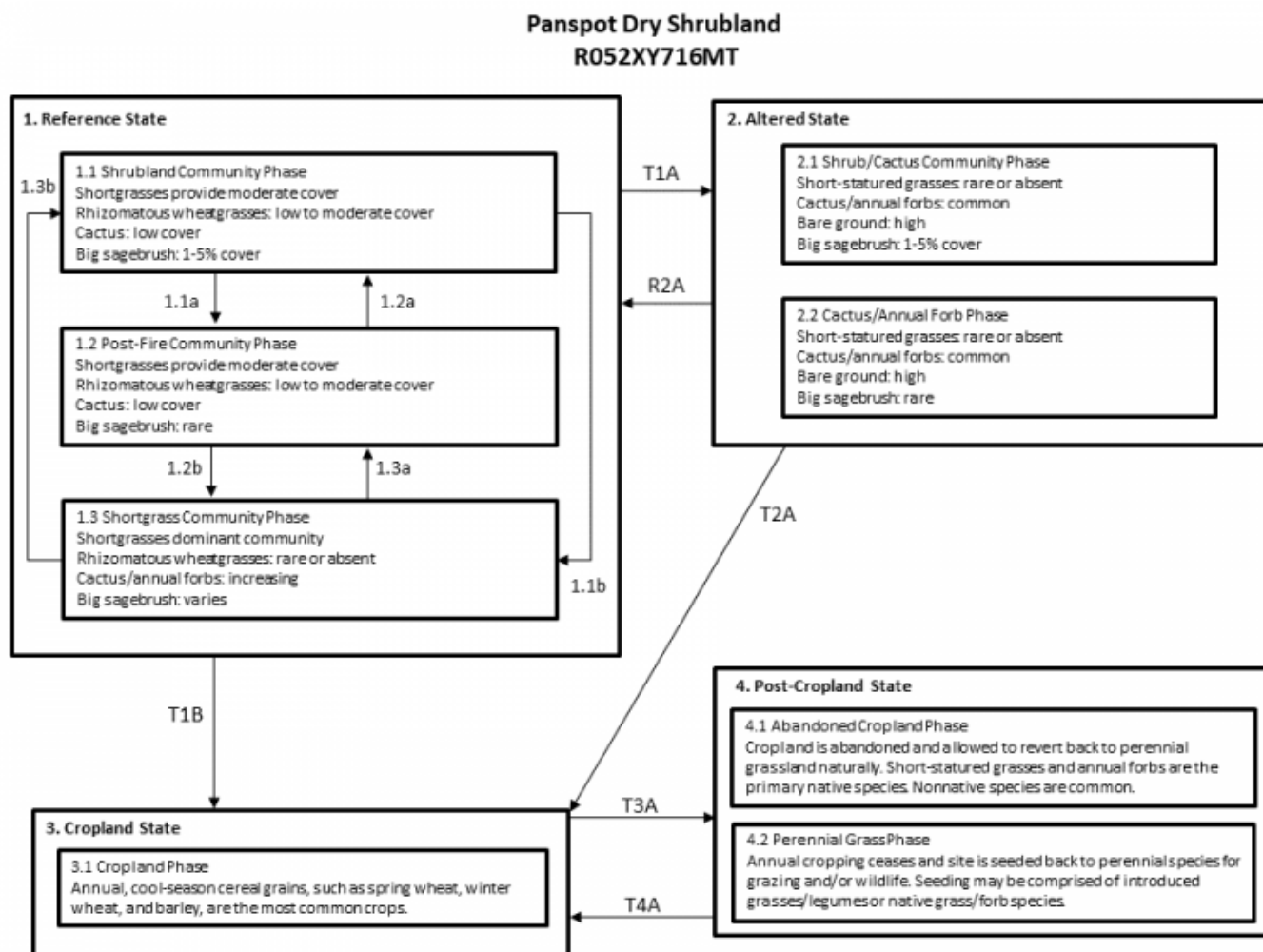


Figure 2. State-and-transition model (STM) diagram.

Panspot Dry Shrubland
R052XY716MT

Legend

- 1.1a - fire
- 1.2a - approximately 30 years post-fire regrowth
- 1.1b, 1.2b - drought, improper grazing management
- 1.3a - normal or above average precipitation, proper grazing management (< 30 years post fire)
- 1.3b - normal or above average precipitation, proper grazing management (≥ 30 years post fire)
- T1A - prolonged drought, improper grazing, or a combination of these factors
- R2A - range seeding, grazing land mechanical treatment, timely moisture, proper grazing management (management intensive and costly)
- T1B, T2A, T4A - conversion to cropland
- T3A - cessation of annual cropping

Figure 2 (continued).

Inventory data references

No data was available specifically for this provisional ecological site. Two historical (417) sites that were labeled Absher series were located, but transects were likely a mix of Panspot and Thin Claypan ecological sites. Data was also obtained from two low-intensity plots representing the Panspot Dry Grassland ecological site. Low-intensity data was collected on an eroded Elloam soil, which is useful for comparison to Panspot Dry Shrubland ecological site, but is technically an unfavorable Thin Claypan ecological site. These plots, in combination with professional experience and a review of the scientific literature, were used to approximate the reference plant community. Information for other states and community phases was obtained from a review of the scientific literature and professional experience. All community phases are considered provisional based on these plots and the sources identified in this ecological site description.

Other references

- Adams, B.W., et al. 2013. Rangeland plant communities for the dry mixedgrass natural subregion of Alberta. Second approximation. Rangeland Management Branch, Policy Division, Alberta Environment and Sustainable Resource Development, Lethbridge, Pub. No. T/040.
- Anderson, R.C. 2006. Evolution and origin of the central grassland of North America: Climate, fire, and mammalian grazers. *Journal of the Torrey Botanical Society* 133:626-647.
- Baskin, J.M., and C.C. Baskin. 1981. Ecology of germination and flowering in the weedy winter annual grass *Bromus japonicus*. *Journal of Range Management* 34:369-372.
- Biondini, M.E., and L. Manske. 1996. Grazing frequency and ecosystem processes in a northern mixed prairie, USA. *Ecological Applications* 6:239-256.
- Biondini, M.E., B.D. Patton, and P.E. Nyren. 1998. Grazing intensity and ecosystem processes in a northern mixed-grass prairie, USA. *Ecological Applications* 8:469-479.
- Bloom-Cornelius, I.V. 2011. Vegetation response to fire and domestic and native ungulate herbivory in a Wyoming big sagebrush ecosystem. M.S. thesis, Oklahoma State University. Stillwater, OK.
- Bragg, T.B. 1995. The physical environment of the Great Plains grasslands. In: A. Joern and K.H. Keeler (eds.) *The Changing Prairie*, Oxford University Press, Oxford, pp. 49–81.

- Branson, D.H., and G.A. Sword. 2010. An experimental analysis of grasshopper community responses to fire and livestock grazing in a northern mixed-grass prairie. *Environmental Entomology* 39:1441-1446.
- Bylo, L.N., N. Koper, and K.A. Molloy. 2014. Grazing intensity influences ground squirrel and American badger habitat use in mixed-grass prairies. *Rangeland Ecology and Management* 67:247-254.
- Christian, J.M., and S.D. Wilson. 1999. Long-term ecosystem impacts of an introduced grass in the Northern Great Plains. *Ecology* 80:2397-2407.
- Clarke, S.E, E.W. Tisdale, and N.A. Skoglund. 1947. The effects of climate and grazing practices on short-grass prairie vegetation in southern Alberta and southwestern Saskatchewan. Canadian Department of Agriculture Technical Bulletin No. 46.
- Cleland, D.T., et al. 1997. National hierarchical framework of ecological units. In: M.S. Boyce and A. Haney (eds.) *Ecosystem Management Applications for Sustainable Forest and Wildlife Resources*, Yale University Press, New Haven, CT.
- Cooper, S.V., C. Jean, and P. Hendricks. 2001. Biological survey of a prairie landscape in Montana's glaciated plains. Report to the Bureau of Land Management. Montana Natural Heritage Program, Helena, MT.
- Cooper, S.V. and W.M. Jones. 2003. Site descriptions of high-quality wetlands derived from existing literature sources. Report to the Montana Department of Environmental Quality. Montana Natural Heritage Program, Helena, MT.
- Coupland, R.T. 1950. Ecology of the mixed prairie of Canada. *Ecological Monographs* 20:271-315.
- Coupland, R.T. 1958. The effects of fluctuations in weather upon the grasslands of the Great Plains. *Botanical Review* 24:273-317.
- Coupland, R.T. 1961. A reconsideration of grassland classification in the Northern Great Plains of North America. *Journal of Ecology* 49:135-167.
- Coupland, R.T., and R.E. Johnson. 1965. Rooting characteristics of native grassland species in Saskatchewan. *Journal of Ecology* 53:475-507.
- Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. US Fish and Wildlife Service FWS/OBS, 79(31), 131.
- Crowe, E., and G. Kudray. 2003. Wetland Assessment of the Whitewater Watershed. Report to U.S. Bureau of Land Management, Malta Field Office. Montana Natural Heritage Program, Helena, MT.
- Davis, S.K., R.J. Fisher, S.L. Skinner, T.L. Shaffer, and R.M. Brigham. 2013. Songbird abundance in native and planted grassland varies with type and amount of grassland in the surrounding landscape. *Journal of Wildlife Management* 77:908-919.
- DeKeyser, E.S., M. Meehan, G. Clambey, and K. Krabbenhoft. 2013. Cool season invasive grasses in northern Great Plains natural areas. *Natural Areas Journal* 33:81-90.
- DeKeyser, S., G. Clambey, K. Krabbenhoft, and J. Ostendorf. 2009. Are changes in species composition on central North Dakota rangelands due to non-use management? *Rangelands* 31:16-19.
- DeLuca, T.H., and P. Lesica. 1996. Long-term harmful effects of crested wheatgrass on Great Plains grassland ecosystems. *Journal of Soil and Water Conservation* 51:408-409.
- Derner, J.D., and R.H. Hart. 2007. Grazing-induced modifications to peak standing crop in northern mixed-grass prairie. *Rangeland Ecology and Management* 60:270-276.

- Derner, J.D., and A.J. Whitman. 2009. Plant interspaces resulting from contrasting grazing management in northern mixed-grass prairie: Implications for ecosystem function. *Rangeland Ecology and Management* 62:83-88.
- Derner, J.D., W.K. Lauenroth, P. Stapp, and D.J. Augustine. 2009. Livestock as ecosystem engineers for grassland bird habitat in the western Great Plains of North America. *Rangeland Ecology and Management* 62:111-118.
- Dix, R.L. 1960. The effects of burning on the mulch structure and species composition of grasslands in western North Dakota. *Ecology* 41:49-56.
- Dormaar, J.F., and S. Smoliak. 1985. Recovery of vegetative cover and soil organic matter during revegetation of abandoned farmland in a semiarid climate. *Journal of Range Management* 38:487-491.
- Dormaar, J.F., and W.D. Willms. 1990. Effect of grazing and cultivation on some chemical properties of soils in the mixed prairie. *Journal of Range Management* 43:456-460.
- Dormaar, J.F., B.W. Adams, and W.D. Willms. 1994. Effect of grazing and abandoned cultivation on a *Stipa-Bouteloua* community. *Journal of Range Management* 47:28-32.
- Dormaar, J.F., M.A. Naeth, W.D. Willms, and D.S. Chanasyk. 1995. Effect of native prairie, crested wheatgrass (*Agropyron cristatum*) and Russian wildrye (*Elymus junceus*) on soil chemical properties. *Journal of Range Management* 48:258-263.
- Fansler, V.A., and J.M. Mangold. 2010. Restoring native plants to crested wheatgrass stands. *Restoration Ecology* 19:16-23.
- Federal Geographic Data Committee. 2008. The National Vegetation Classification Standard, Version 2. FGDC Vegetation Subcommittee. FGDC-STD-005-2008 (Version 2). pp. 126.
- Fullerton, D.S., and R.B. Colton. 1986. Stratigraphy and correlation of the glacial deposits on the Montana Plains. U.S. Geological Survey.
- Fullerton, D.S., R.B. Colton, C.A. Bush, and A.W. Straub. 2004. Map showing spatial and temporal relations of mountain and continental glaciations on the northern plains, primarily in northern Montana and northwestern North Dakota. U.S. Geologic Survey pamphlet accompanying Scientific Investigations Map 2843.
- Fullerton, D.S., R.B. Colton, and C.A. Bush. 2013. Quaternary geologic map of the Shelby 1° x 2° quadrangle, Montana: U.S. Geological Survey Open-File Report 2012-1170, scale 1:250,000.
- Galatowitsch, S.M., and A.G. Van der Valk. 1996. The vegetation of restored and natural prairie wetlands. *Ecological Applications*. 6:1 pp.102-112.
- Gilbert, M.C., P.M. Whited, E.J. Clairain Jr., and R.D. Smith. 2006. A regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of prairie potholes. U.S. Army Corps of Engineers Final Report, Washington, DC.
- Grant, T.A., B. Flanders-Wanner, T.L. Shaffer, R.K. Murphy, and G.A. Knutsen. 2009. An emerging crisis across northern prairie refuges: Prevalence of invasive plants and a plan for adaptive management. *Ecological Restoration* 27:58-65.
- Haferkamp, M.R., R.K. Heitschmidt, and M.G. Karl. 1997. Influence of Japanese brome on western wheatgrass yield. *Journal of Range Management* 50:44-50.
- Hansen, P.L., et al. 1995. Classification and management of Montana's riparian and wetland sites. University of Montana, Montana Forest and Conservation Experiment Station, Miscellaneous Publication No. 54.
- Harmoney, K.R. 2007. Grazing and burning Japanese brome (*Bromus japonicus*) on mixed grass rangelands. *Rangeland Ecology and Management* 60:479-486.

- Hart, M., S.S. Waller, S.R. Lowry, and R.N. Gates. 1985. Disking and seeding effects on sod bound mixed prairie. *Journal of Range Management* 38:121-125.
- Heidel, B., S.V. Cooper, and C. Jean. 2000. Plant species of special concern and plant associations of Sheridan County, Montana. Report to U.S. Fish and Wildlife Service. Montana Natural Heritage Program, Helena, MT.
- Heidinga, L., and S.D. Wilson. 2002. The impact of an invading alien grass (*Agropyron cristatum*) on species turnover in native prairie. *Diversity and Distributions* 8:249-258.
- Heitschmidt, R.K., and L.T. Vermeire. 2005. An ecological and economic risk avoidance drought management decision support system. In: J.A. Milne (ed.) *Pastoral Systems in Marginal Environments*, XXth International Grasslands Congress, July 2005, p. 178.
- Henderson, A.E., and S.K. Davis. 2014. Rangeland health assessment: A useful tool for linking range management and grassland bird conservation? *Rangeland Ecology and Management* 67:88-98.
- Henderson, D.C., and M.A. Naeth. 2005. Multi-scale impacts of crested wheatgrass invasion in mixed-grass prairie. *Biological Invasions* 7:639-650.
- Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M. Burkett, and W.G. Whitford. 2009. Monitoring manual for grassland, shrubland and savanna ecosystems. U.S. Department of Agriculture, Agricultural Research Service, Jornada Experimental Range, Las Cruces, NM.
- Higgins, K.F. 1986. Interpretation and compendium of historical fire accounts in the Northern Great Plains. U.S. Fish and Wildlife Service Resource Publication 161.
- Holechek, J.L. 1981. Crested wheatgrass. *Rangelands* 3:151-153.
- Howard, J.L. 1999. *Artemisia tridentata* subsp. *wyomingensis*. In: Fire Effects Information System, U.S. Department of Agriculture, Forest Service <http://www.fs.fed.us/database/feis/plants/shrub/artriw/all.html> (accessed 8/11/2016).
- Joern, A. 2005. Disturbance by fire frequency and bison grazing modulate grasshopper assemblages in tallgrass prairie. *Ecology* 86:861-873.
- Jones, W.M. 2004. Using vegetation to assess wetland condition: a multimetric approach for temporarily and seasonally flooded depression wetlands and herbaceous-dominated intermittent and ephemeral riverine wetlands in the northwestern glaciated plains ecoregion, Montana. Report to the Montana Department of Environmental Quality and the U.S. Environmental Protection Agency. Montana Natural Heritage Program, Helena, MT.
- Knopf, F.L. 1996. Prairie legacies—birds. In: F.B. Samson and F.L. Knopf (eds.) *Prairie Conservation: Preserving North America's Most Endangered Ecosystem*, Island Press, Washington, DC, pp. 135-148.
- Knopf, F.L., and F.B. Samson. 1997. Conservation of grassland vertebrates. In: F.B. Samson and F.L. Knopf (eds.) *Ecology and Conservation of Great Plains Vertebrates: Ecological Studies* 125, Springer-Verlag, New York, NY, pp. 273-289.
- Krzic, M., K. Broersma, D.J. Thompson, and A.A. Bomke. 2000. Soil properties and species diversity of grazed crested wheatgrass and native rangelands. *Journal of Range Management* 53:353-358.
- Lacey, J., R. Carlstrom, and K. Williams. 1995. Chiseling rangeland in Montana. *Rangelands* 17:164-166.
- Lauenroth, W.K., O.E. Sala, D.P. Coffin, and T.B. Kirchner. 1994. The importance of soil water in recruitment of *Bouteloua gracilis* in the shortgrass steppe. *Ecological Applications* 4:741-749.
- Laycock, W.A. 1988. History of grassland plowing and grass planting on the Great Plains. In: J.E. Mitchell (ed.) *Impacts of the Conservation Reserve Program in the Great Plains—Symposium Proceedings*, September 16-18, 1987. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-158.

- Laycock, W.A. 1991. Stable states and thresholds of range condition on North American rangelands. *Journal of Range Management* 44:427-433.
- Lesica, P., and P. Husby. 2006. *Field Guide to Montana's Wetland Vascular Plants*. Montana Wetlands Trust. Helena, MT.
- Lockwood, J.A. 2004. *Locust: The devastating rise and mysterious disappearance of the insect that shaped the American frontier*. Basic Books, New York, NY.
- Looman, J., and D.H. Heinrichs. 1973. Stability of crested wheatgrass pastures under long-term pasture use. *Canadian Journal of Plant Science* 53:501-506.
- Madden, E.M., R.K. Murphy, A.J. Hansen, and L. Murray. 2000. Models for guiding management of prairie bird habitat in northwestern North Dakota. *American Midland Naturalist* 144:377-392.
- McNab, W.H., et al. 2007. Description of ecological subregions: Sections of the conterminous United States [CD-ROM]. USDA Forest Service, General Technical Report WO-76B.
- McIntyre, C., K. Newlon, L. Vance, and M. Burns. 2011. Milk, Marias, and St. Mary monitoring: developing a long-term rotating basin wetland assessment and monitoring strategy for Montana. Report to the United States Environmental Protection Agency. Montana Natural Heritage Program, Helena, MT.
- Miller, J.J., and J.A. Brierley. 2011. Solonchic soils of Canada: Genesis, distribution, and classification. *Canadian Journal of Soil Science* 91:889-902.
- Montana State College. 1949. Similar vegetative rangeland types in Montana. Montana State College, Agricultural Experiment Station.
- Mushet, D.M., N.H. Euliss, Jr., and C.A. Stockwell. 2012. A conceptual model to facilitate amphibian conservation in the Northern Great Plains. *Great Plains Research* 22:45-58.
- Nesser, J.A., G.L. Ford, C.L. Maynard, and D.S. Page-Dumroese. 1997. Ecological units of the Northern Region: Subsections. USDA Forest Service, Intermountain Research Station, General Technical Report INT-GTR-369.
- Oard, M.J. 1993. A method of predicting chinook winds east of the Montana Rockies. *Weather and Forecasting* 8:166-180.
- Ogle, S.M., W.A. Reiners, and K.G. Gerow. 2003. Impacts of exotic annual brome grasses (*Bromus* spp.) on ecosystem properties of the northern mixed grass prairie. *American Midland Naturalist* 149:46-58.
- Roath, L.R. 1988. Implications of land conversions and management for the future. In: J.E. Mitchell (ed.) *Impacts of the Conservation Reserve Program in the Great Plains—Symposium Proceedings, September 16-18, 1987*. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-158.
- Rogler, G.A., and R.J. Lorenz. 1983. Crested wheatgrass: Early history in the United States. *Journal of Range Management* 36:91-93.
- Romo, J.T. 2011. Clubmoss, precipitation, and microsite effects on emergence of graminoid and forb seedlings in the semiarid northern mixed prairie of North America. *Journal of Arid Environments* 75:98-105.
- Rowe, J.S. 1969. Lightning fires in Saskatchewan grassland. *Canadian Field Naturalist* 83:317-327.
- Salo, E.D., et al. 2004. Grazing intensity effects on vegetation, livestock and non-game birds in North Dakota mixed-grass prairie. *Proceedings of the 19th North American Prairie Conference, Madison, WI*.
- Samuel, M.J., and R.H. Hart. 1994. Sixty-one years of secondary succession on rangelands of the Wyoming High Plains. *Journal of Range Management* 47:184-191.

- Semlitsch, R.D. 2000. Principles for management of aquatic-breeding amphibians. *Journal of Wildlife Management* 64:615-631.
- Shay, J., D. Kunec, and B. Dyck. 2001. Short-term effects of fire frequency on vegetation composition and biomass in mixed prairie in south-western Manitoba. *Plant Ecology* 155:157-167.
- Smith, B., and G.J. McDermid. 2014. Examination of fire-related succession within the dry mixed-grass subregion of Alberta with the use of MODIS and Landsat. *Rangeland Ecology and Management* 67:307-317.
- Smith, R.E. 2013. Conserving Montana's sagebrush highway: Long distance migration in sage-grouse. M.S. thesis, University of Montana, Missoula, MT.
- Smoliak, S. 1974. Range vegetation and sheep production at three stocking rates on *Stipa-Bouteloua* prairie. *Journal of Range Management* 27:23-26.
- Smoliak, S., and J.F. Dormaar. 1985. Productivity of Russian wildrye and crested wheatgrass and their effect on prairie soils. *Journal of Range Management* 38:403-405.
- Smoliak, S., J.F. Dormaar, and A. Johnston. 1972. Long-term grazing effects on *Stipa-Bouteloua* prairie soils. *Journal of Range Management* 25:246-250.
- Soil Survey Staff. 2014. Keys to soil taxonomy, 12th edition. USDA Natural Resources Conservation Service.
- Soller, D.R. 2001. Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains. U.S. Geological Survey Miscellaneous Investigations Series I-1970-E, scale 1:3,500,000.
- Stephens, S.E., J.J. Rotella, M.S. Lindberg, M.L. Taper, and J.K. Ringelman. 2005. Duck nest survival in the Missouri Coteau of North Dakota: Landscape effects at multiple spatial scales. *Ecological Applications* 15:2137-2149.
- Stewart, R.E., and H.A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. No. 92. US Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife.
- Tiner, R.W. 2003. Correlating Enhanced National Wetlands Inventory Data with Wetland Functions for Watershed Assessments: A Rationale for Northeastern U.S. Wetlands. U.S. Fish and Wildlife Service, National Wetlands Inventory Program, Region 5, Hadley, MA.
[http://www.fws.gov/northeast/wetlands/pdf/CorrelatingEnhancedNWIDataWetlandFunctionsWatershedAssessments\[1\].pdf](http://www.fws.gov/northeast/wetlands/pdf/CorrelatingEnhancedNWIDataWetlandFunctionsWatershedAssessments[1].pdf).
- Toledo, D., M. Sanderson, K. Spaeth, J. Hendrickson, and J. Printz. 2014. Extent of Kentucky bluegrass and its effect on native plant species diversity and ecosystem services in the Northern Great Plains of the United States. *Invasive Plant Science and Management* 7:543-552.
- Umbanhowar, Jr., C.E. 2004. Interactions of climate and fire at two sites in the Northern Great Plains. *Palaeogeography, Palaeoclimatology, and Palaeoecology* 208:141-152.
- U.S. Department of Agriculture, Natural Resources Conservation Service. Glossary of landform and geologic terms. National Soil Survey Handbook, Title 430-VI, Part 629.02c.
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054242 (accessed 13 April 2016).
- U.S. Fish and Wildlife Service. 2013. Greater sage-grouse (*Centrocercus urophasianus*) conservation objectives: Final report.
- Vance, L., S. Owen, and J. Horton. 2013. Literature review: Hydrology-ecology relationships in Montana prairie wetlands and intermittent/ephemeral streams. Report to the Cadmus Group and the U.S. Environmental Protection Agency. Montana Natural Heritage Program, Helena, MT.

- Van Dyne, G.M., and W.G. Vogel. 1967. Relation of *Selaginella densa* to site, grazing, and climate. *Ecology* 48:438-444.
- Vaness, B.M., and S.D. Wilson. 2007. Impact and management of crested wheatgrass (*Agropyron cristatum*) in the northern Great Plains. *Canadian Journal of Plant Science* 87:1023-1028.
- Vermeire, L.T., J.L. Crowder, and D.B. Wester. 2011. Plant community and soil environment response to summer fire in the northern Great Plains. *Rangeland Ecology & Management* 64:37-46.
- Vermeire, L.T., J.L. Crowder, and D.B. Wester. 2014. Semiarid rangeland is resilient to summer fire and postfire grazing utilization. *Rangeland Ecology & Management* 67:52-60.
- Vuke, S.M., K.W. Porter, J.D. Lonn, and D.A. Lopez. 2007. Geologic map of Montana - information booklet: Montana Bureau of Mines and Geology Geologic Map 62-D.
- Wambolt, C.L., K.S. Walhof, and M.R. Frisina. 2001. Recovery of big sagebrush communities after burning in south-western Montana. *Journal of Environmental Management*. 61:243-252.
- Watts, M.J., and C.L. Wambolt. 1996. Long-term recovery of Wyoming big sagebrush after four treatments. *Journal of Environmental Management* 46:95-102.
- Whisenant, S.G. 1990. Postfire population dynamics of *Bromus japonicus*. *American Midland Naturalist* 123:301-308.
- Wilson, S.D., and J.M. Shay. 1990. Competition, fire, and nutrients in a mixed-grass prairie. *Ecology* 71:1959-1967.
- With, K.A. 2010. McCown's longspur (*Rhynchophanes mccownii*). In: A. Poole (ed.) *The Birds of North America* (online), Cornell Lab of Ornithology, Ithaca. <http://bna.birds.cornell.edu/bna/species/09>.

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Approval

Scott Brady, 7/03/2019

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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:**
