USDA Natural Resources
Conservation Service

Ecological site FX052X01X007
Coarse Clay (Coc) Dry Grassland

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General information

Provisional. A provisional ecological site description has undergone quality control and quality assurance review. It contains a working state and transition model and enough information to identify the ecological site.

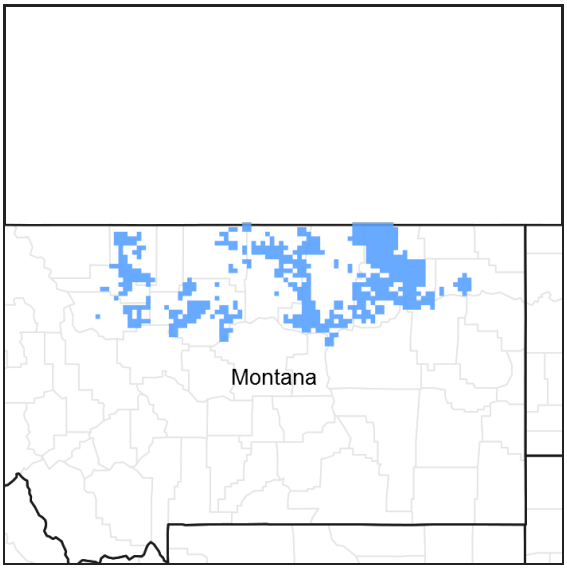

Figure 1. Mapped extent

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

MLRA notes

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

The Brown Glaciated Plains, MLRA 52, is an expansive and agriculturally and ecologically significant area. It consists of around 14.5 million acres 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). 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 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: Dry Grassland

National Hierarchical Framework of Ecological Units (Cleland et al., 1997; McNab et al., 2007)
• Domain: Dry
• Division: Temperate Steppe
• Province: Great Plains-Palouse Dry Steppe Province 331
• Section: Northwestern Glaciated Plains 331D
• Subsection: Montana Glaciated Plains 331Dh
• Landtype association/Landtype phase: N/A

National Vegetation Classification Standard (Federal Geographic Data Committee, 2008)
• Class: Mesomorphic Shrub and Herb Vegetation Class (2)
• Subclass: Temperate and Boreal Grassland and Shrubland Subclass (2.B)
• Formation: Temperate Grassland, Meadow, and Shrubland Formation (2.B.2)
• Division: Great Plains Grassland and Shrubland Division (2.b.2.Nb)
• Macrogroup: Andropogon hallii - Calamovilfa longifolia - Artemisia filifolia Great Plains Sand Grassland & Shrubland Macrogroup (2.B.2.Nb.4)
• Group: Andropogon hallii - Calamovilfa longifolia - Hesperostipa comata Sand Grassland Group (2.B.2.Nb.4.b)
• Alliance: Calamovilfa longifolia Sand Prairie Alliance (2.B.2.Nb.4.b)

• Association: None identified

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

Ecological site concept

This provisional ecological site occurs in the Dry Grassland climatic zone of MLRA 52. Figure 1 illustrates the distribution of this ecological site based on current data. This map is approximate, is not intended to be definitive, and may be subject to change. Onsite evaluations are necessary, particularly in boundary or intergrade areas where ecological sites from multiple climate zones may overlap. Coarse Clay Dry Grassland is an ecological site of limited-extent occurring on dissected till plain landscapes in MLRA 52. This ecological site occurs on till plains, hillslopes, and bluffs where erosion has removed glacial till and exposed the underlying bedrock. Soils are clayey, but the surface horizon has a strong granular structure that mimics sand. Soil depth is typically less than 20 inches to bedrock. Slopes vary from 0 to 60 percent, but are typically greater than 15 percent.

The distinguishing characteristics of this site are a clay content greater than 35 percent and strong granular structure in the surface horizon. Soils are derived from clayey residuum or from clayey alluvium over shale. Soil surface textures (upper 4 inches) contain more than 35 percent clay. Underlying horizons are typically weakly developed and commonly contain shale fragments. Calcium carbonate equivalent and pH vary widely. This site is typically acid with little or no calcium carbonate, but in some cases it may be alkaline with up to 15 percent calcium carbonate. Vegetation is typically sparse and soil exposure relatively high. Characteristic vegetation is prairie sandreed (Calamovilfa longifolia) and creeping juniper (Juniperus horizontalis).

Associated sites

FX052X01X131	**Shallow Clay (Swc) Dry Grassland** This site occurs on moderate to steeply sloping hillslopes adjacent to the Coarse Clay Dry Grassland site. It is frequently in the same landscape positions but has different soil structure and is nonacid.
FX052X01X005	**Clayey-Steep (Cystp) Dry Grassland** This site occurs on moderate to steeply sloping hillslopes adjacent to the Coarse Clay Dry Grassland site. It is generally in backslope positions where bedrock is at a depth of 20 inches or more.

Similar sites

FX052X03X007	**Coarse Clay (Coc) Dry Shrubland** This site differs from Coarse Clay Dry Grassland in that it has slightly warmer annual temperatures and supports big sagebrush rather than silver sagebrush.
FX052X01X005	**Clayey-Steep (Cystp) Dry Grassland** This site differs from Coarse Clay Dry Grassland in that depth to bedrock is 20 inches or more and soil structure in the surface horizon is weak fine rather than strong granular.
FX052X01X131	**Shallow Clay (Swc) Dry Grassland** This site differs from Coarse Clay Dry Grassland in that the soil surface horizon structure is fine weak rather than strong granular. Prairie sandreed does not dominate the plant community.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified
Herbaceous	Not specified

Legacy ID

R052XY007MT

Physiographic features

Coarse Clay Dry Grassland is a limited-extent ecological site occurring on hillslopes, till plains and bluffs in MLRA 52. The majority of MLRA 52 is covered by a broad till plain, and this ecological site largely occurs where the till plain has been dissected by streams or rivers and underlying bedrock has been exposed. This site is typically in backslope positions on till plains, hillslopes, and bluffs. Slopes are typically 15 to 60 percent.

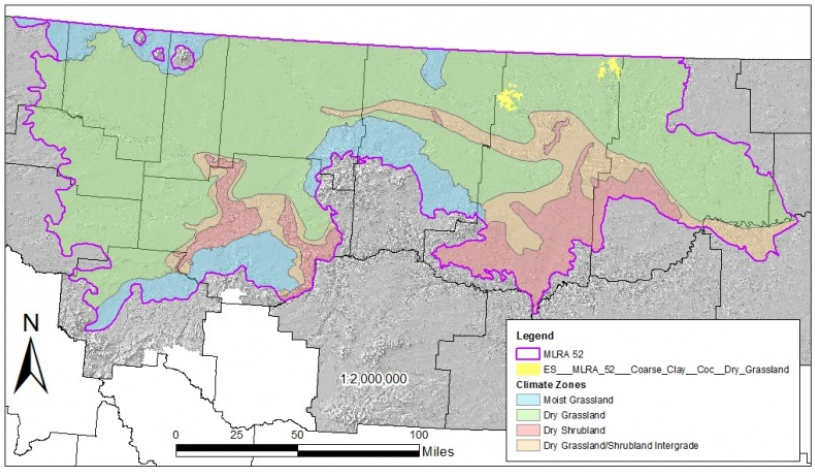

Figure 2. Figure 1. General distribution of the Coarse Clay Dry Grassland ecological site by map unit extent.

Table 2. Representative physiographic features

Landforms	(1) Till plain > Hillslope (2) Till plain > Bluff
Elevation	610–1,180 m
Slope	0–60%
Aspect	Aspect is not a significant factor

Climatic features

The Brown Glaciated Plains is a semi-arid region with a temperate continental climate that is characterized by frigid winters and warm to hot summers (Cooper et al., 2001). The average frost-free period for this ecological site is 120 days. The majority of precipitation occurs as steady, soaking, frontal system rains in late spring to early summer. Summer rainfall comes mainly from convection thunderstorms that typically deliver scattered amounts of rain in intense bursts. These storms may be accompanied by damaging winds and large-diameter hail and result in flash flooding along low-order streams. Severe drought occurs on average in 2 out of 10 ten years. Annual precipitation ranges from 10 to 14 inches, and 70 to 80 percent of this occurs during the growing season (Cooper et al., 2001). Extreme climatic variations, especially droughts, have the greatest influence on species cover and production (Coupland, 1958, 1961; Biondini et al., 1998).

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

Table 3. Representative climatic features

Frost-free period (average)	120 days
Freeze-free period (average)	140 days
Precipitation total (average)	305 mm

Climate stations used

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

Influencing water features

This is a dry upland site, and the water budget is normally contained within the soil profile. Because of steep slopes and the soil's high clay content, result in very high runoff potential. Intense precipitation events deliver large amounts of surface runoff downslope. Moisture loss through evapotranspiration exceeds precipitation for the majority of the growing season. Soil moisture levels are greatest in May and June but rarely reach field capacity. Soil moisture is the primary limiting factor for plant production on this ecological site.

Soil features

The soil that best represents the central concept of this ecological site is Volborg. This soil is in the Ustorthents great group. It is characterized by a surface horizon that lacks enough organic matter to have a mollic epipedon, contact with paralithic bedrock within 20 inches of the soil surface, and strong granular structure in the surface horizon. The family is clayey, and minerology is smectitic. 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. All soils have a frigid soil temperature regime (Soil Survey Staff, 2014).

Surface textures found in this site are typically silty clay loam, silty clay or clay and contain more than 35 percent clay. Soil structure in the surface horizon is moderate fine granular to strong medium granular. Underlying horizons are weakly developed and frequently contain shale chips. Organic matter in the surface horizon typically ranges from 1 to 2 percent, and moist colors vary from olive brown (2.5Y 4/3) to dark gray (2.5Y 4/1). Darker colors are typically inherited from the parent material and are not a result of an accumulation of organic matter. As the majority of this site is formed in the non-calcareous Bearpaw formation, the upper 5 inches of these soils typically do not react with hydrochloric acid. However, when this site exists in other formations or where calcareous till or slope alluvium is present the surface may react strongly or violently. The calcium carbonate equivalent in the upper 5 inches is typically negligible but can range up to 14 percent. Soil pH class ranges from very strongly acid to strongly alkaline in the surface and subsurface horizons. The soil depth class for this site is shallow or very shallow (less than 20 inches to bedrock). Content of coarse fragments is typically between 15 and 60 percent by volume in the subsurface horizons. These fragments are typically soft parafragments that are weakly cemented and can be crushed between the fingers.

Table 4. Representative soil features

Parent material	(1) Residuum–shale
Surface texture	(1) Silty clay loam (2) Silty clay (3) Clay
Drainage class	Well drained
Soil depth	0–51 cm
Available water capacity (0-101.6cm)	3.81–5.08 cm

Calcium carbonate equivalent (0-12.7cm)	0–14%
Electrical conductivity (0-50.8cm)	0–3 mmhos/cm
Sodium adsorption ratio (0-50.8cm)	0–12
Soil reaction (1:1 water) (0-101.6cm)	4.5–9
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), 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 Coarse Clay provisional ecological site in MLRA 52 Dry Grassland consists of three states: The Reference State (1.0), the Altered State (2.0) and the Invaded State (3.0). Plant communities associated with this ecological site evolved under the combined influences of climate, grazing, and fire. Extreme climatic variability results in frequent droughts, which have the greatest influence on the relative contribution of species cover and production (Coupland, 1958, 1961; Biondini et al., 1998). Due to the dominance of cool-season graminoids, annual production is highly dependent upon mid- to late-spring precipitation (Heitschmidt and Vermeire, 2005; Anderson, 2006).

Native grazers also shaped these plant communities. American bison (Bison bison) were the dominant historic grazer, but pronghorn (Antilocapra americana), elk (Cervus canadensis), and deer (Odocoileus spp.) were also common. Additionally, small mammals such as prairie dogs (Cynomys spp.) and ground squirrels (Urocitellus spp.) influenced this plant community (Salo et al., 2004). Grasshoppers and periodic outbreaks of Rocky Mountain locusts (Melanoplus spretus; Lockwood, 2004) also played an important role in the ecology of these communities.

The historic ecosystem also experienced relatively frequent lightning-caused fires with estimated fire return intervals of 6 to 25 years (Bragg, 1995). Historically, Native Americans also set frequent fires. The majority of lightning-caused fires occurred in July and August, whereas Native Americans typically set fires during spring and fall to correspond with the movement of bison (Higgins, 1986). It is not known how significant fire was on the Coarse Clay Dry Grassland ecological site. However, due to the sparse vegetation and rough, broken topography, its effects were most likely minimal. Further investigation of fire dynamics is needed to better assess this.

Drought or improper grazing of this site can result in a reduction in the cover and vigor of the warm-season grasses, reduced vigor in cool-season grasses, and an increase in unpalatable forbs and shrubs. 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. Further degradation of the site due to improper grazing can result in a community dominated by low shrubs and unpalatable forbs such as curlycup gumweed (*Grindelia squarrosa*). Periods of extended drought (approximately 3 years or more) may have similar effects. Non-native annual bromes have become naturalized in relatively undisturbed grasslands (Ogle et al., 2003; Harmoney, 2007) and can be present in any state within the scope of this ecological site. Their abundance varies depending on precipitation and germination conditions. Under normal conditions, they typically do not have a significant ecological impact on this ecological site. It is hypothesized that prolonged improper grazing combined with the introduction of invasive species may result in an invaded state. Possible invasive species include field, or Japanese, brome (*Bromus arvensis*), saltlover (*Halogeton glomeratus*), and noxious weeds. This state has not been conclusively documented, and the ecological mechanisms are unclear. The invaded state is considered hypothetical until further investigation of invasive species dynamics can be completed.

Because of the shallow soil and generally steep slopes, this ecological site is unsuitable for cropland. Therefore, this ecological site has remained in native vegetation.

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

State 1: Reference State
The Reference State contains two community phases characterized by mid-statured warm-season grasses and low shrubs. 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 site is believed to have been protected from fire by topography and low fuel loads, but fire dynamics on this site are not well understood. Because of a relatively high occurrence of bare ground and the difficult growing conditions, this site is sensitive to disturbances.

Community Phase 1.1: Warm Season Grass Phase
The reference plant community on this site is characterized by an abundance of mid-statured warm-season grasses and creeping juniper. By far, the most common grass is the warm-season prairie sandreed, which may constitute up to 50 percent of the total annual production. Little bluestem may also be present and commonly occurs in large patches. Cool-season grasses are subdominant and may include western wheatgrass and prairie Junegrass. Prairie clover (Dalea spp.) is common if the site is nonacid but is generally absent if the pH is less than 6.1. Other common forbs are American vetch (*Vicia americana*) and fewflower buckwheat (*Eriogonum pauciflorum*). Low shrubs are common but comprise 10 percent or less of the total canopy cover. Common species are creeping juniper and longleaf wormwood (*Artemisia longifolia*). The approximate species composition of the reference plant community is as follows:

Percent composition by weight*
Prairie Sandreed 30-50%
Little Bluestem 0-20%
Cool-Season Grasses 15%
Other Native Grasses 10%
Native Perennial Forbs 15%
Shrubs/Subshrubs 10%

Estimated Total Annual Production (lbs/ac)*
Low - 200
Representative Value - 350
High - 500
*Estimated based on current observation – subject to revision

Community Phase 1.2: At-Risk Community Phase
The At-Risk Community Phase is characterized by a significant reduction of mid-statured warm-season grasses. Cool-season grasses, predominantly short-statured species such as prairie Junegrass, exhibit poor vigor and low cover. Unpalatable forbs such as curlycup gumweed are increasing in this phase. Low shrubs, particularly common juniper, are common and increasing.

Community Phase Pathway 1.1a
Drought, improper grazing management, or a combination of these factors can shift the reference community phase (1.1) to the At-Risk Community Phase (1.2).

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

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. Low shrubs and unpalatable forbs dominate the plant community.

Transition T1B
The Reference State (1) transitions to the Invaded State (3) when aggressive invasive species or noxious weeds invade the Altered State (2). It is hypothesized that invasive species will significantly alter ecological properties, but the ecological mechanisms of this transition are unclear and need further study.

State 2: Altered State
The Altered State consists of one community phase. The dynamics of this state are driven by long-term drought, improper grazing management, or a combination of these factors. The Altered State is dominated by low shrubs and unpalatable forbs such as curlycup gumweed. Perennial grasses have been eliminated or nearly so, and their vigor and production are low. Once in the Altered State, the site may become unstable and is subject to erosion and solar heating.

Community Phase 2.1: Shrub/Forb Phase
Low shrubs, particularly creeping juniper, dominate this community phase. Longleaf wormwood, more commonly known as longleaf sagebrush, may be common in acidic areas while broom snakeweed is significant in nonacid areas. Unpalatable forbs such as curlycup gumweed and prairie thermopsis (*Thermopsis rhombifolia*) are common. Perennial grasses have been eliminated or nearly so. There is a high amount of bare ground, and soils are unstable and subject to erosion.

Restoration Pathway R2A
A change in management alone may not be sufficient to restore the Altered State to the Reference State. Intensive restoration methods may be necessary to reestablish desirable species. Reseeding via conventional methods may not be possible due to the steep topography of this site. Specialized reseeding techniques (hydroseeding, use of straw wattles, etc.) may be necessary. These restoration methods are labor intensive and costly and may not be practical in all situations.

Transition T2A
The Altered State (2) transitions to the Invaded State (3) when aggressive invasive species or noxious weeds invade the Altered State (2). It is hypothesized that invasive species will significantly alter ecological properties, but the ecological mechanisms of this transition are unclear and need further study.

State 3: Invaded State
The Invaded State (3) occurs primarily when invasive, non-native species invade native grassland communities. Anecdotal observations of this state have been made, but conclusive documentation has not yet been obtained. This state is considered hypothetical until further investigation of invasive species dynamics can be completed. Possible invasive species include Japanese brome, saltlover, or halogeton, and noxious weeds.

State and transition model

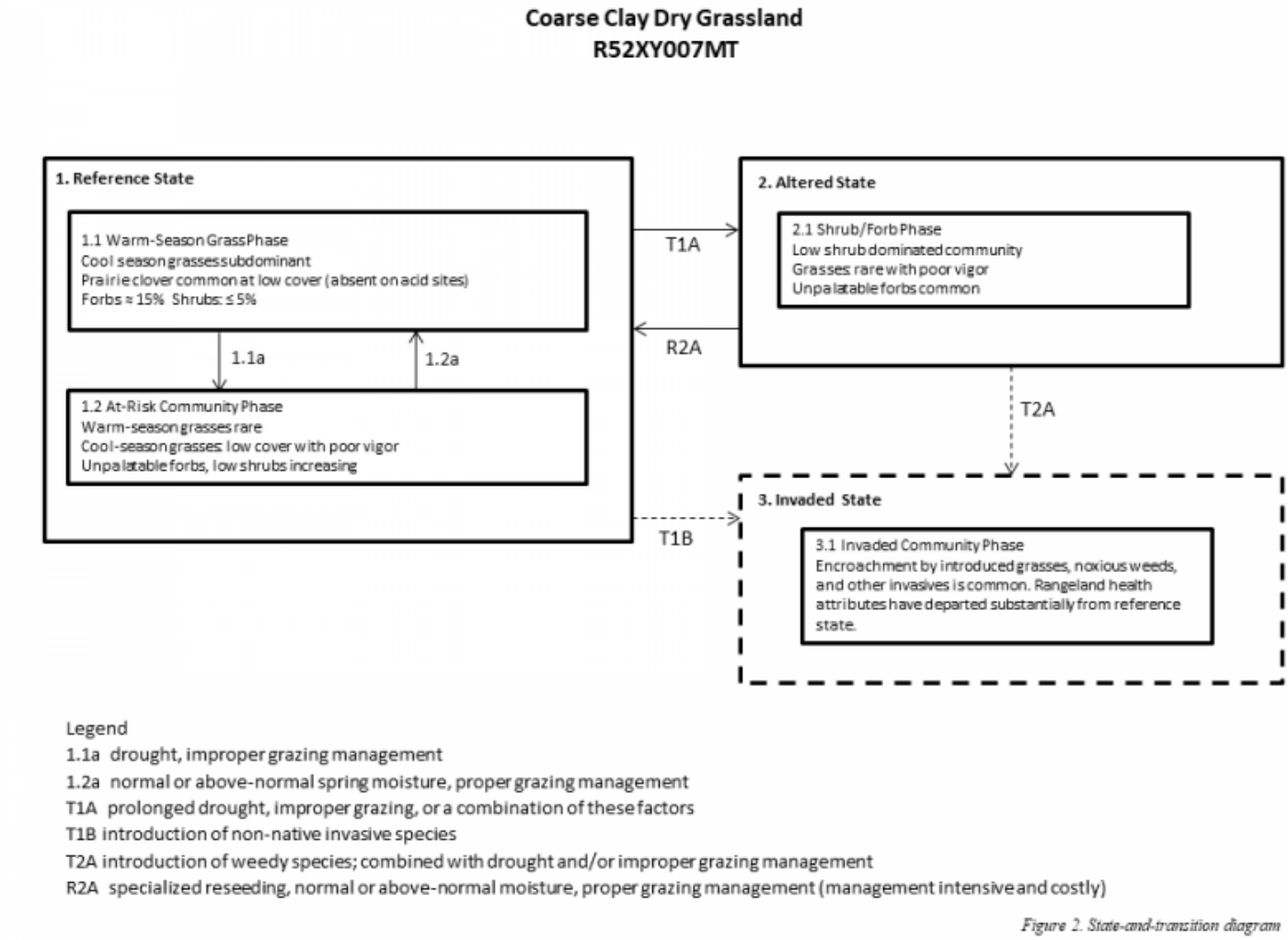

Figure 2. State-and-transition diagram

Inventory data references

Two historical (417) plots were available for this ecological site. These were supplemented with one low-intensity plot for the Coarse Clay Dry Shrubland site and with available literature. These data were used to approximate the reference plant community for this provisional ecological site. Information for alternate 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 document.

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.

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.

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.

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.

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.

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 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.

Federal Geographic Data Committee. 2008. The national vegetation classification standard, version 2. FGDC Vegetation Subcommittee, FGDC-STD-005-2008 (Version 2), p. 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.

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.

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, Montana.

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.

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.

Joern, A. 2005. Disturbance by fire frequency and bison grazing modulate grasshopper assemblages in tallgrass prairie. Ecology 86:861-873.

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.

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.

Lockwood, J.A. 2004. Locust: The devastating rise and mysterious disappearance of the insect that shaped the American frontier. Basic Books, New York, NY.

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.

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.

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, Wisconsin.

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.

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., 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.

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.

USDA 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 April 13, 2016)

USDA Natural Resources Conservation Service. 2016. Plant guide for broom snakeweed. http://plants.usda.gov/plantguide/pdf/cs_gusa2.pdf (Accessed April 22, 2016)

U.S. Fish and Wildlife Service. 2013. Greater sage-grouse (Centrocercus urophasianus) conservation objectives: Final report.

Van Dyne, G.M., and W.G. Vogel. 1967. Relation of Selaginella densa to site, grazing, and climate. Ecology 48:438-444.

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.

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/096

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Approval

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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:**

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

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

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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:**

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17. **Perennial plant reproductive capability:**
