

# Ecological site EX044B01B131

## Shallow Clay (SwC) LRU 01 Subset B

Last updated: 9/11/2023  
Accessed: 05/18/2024

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### General information

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

### MLRA notes

Major Land Resource Area (MLRA): 044B—Central Rocky Mountain Valleys

Major Land Resource Area (MLRA) 44B, Central Rocky Mountain Valleys, is nearly 3.7 million acres of southwest Montana. This MLRA borders two other MLRAs: 43B, Central Rocky Mountains and Foothills, and 46, Northern and Central Rocky Mountain Foothills.

The major watersheds of this MLRA are the Missouri and Yellowstone Rivers and their associated headwaters, such as the Beaverhead, Big Hole, Jefferson, Ruby, Madison, Gallatin, and Shields Rivers. Limited portions of the MLRA are west of the Continental Divide along the Clark Fork River. These waters allow for extensive irrigation for crop production in an area that is generally only compatible with rangeland and grazing. The Missouri River and its headwaters are behind several reservoirs used for irrigation water, hydroelectric power, and municipal water.

The primary land use of this MLRA is production agriculture (grazing, small grain production, and hay) with limited mining. Urban development is high, with large expanses of rangeland being converted to subdivisions for a rapidly growing population.

MLRA 44B consists of one Land Resource Unit (LRU) and seven climate-based LRU subsets. Annual precipitation ranges from a low of 9 inches to a high of near 24 inches. The driest areas tend to be in the valley bottoms of southwest Montana, in the rain shadow of the mountains. The wettest portions tend to be near the edges of the MLRA, where it borders MLRA 43B. Frost-free periods also vary greatly, with less than 30 days in the Big Hole Valley to approximately 110 days in the warm valleys along the Yellowstone and Missouri Rivers.

MLRA 44B's plant communities are highly variable but are dominated by a cool-season grass and shrub-steppe community on the rangeland and a mixed coniferous forest in the mountains. Warm-season grasses occupy an extremely limited extent and number of species in this MLRA. Most subspecies of big sagebrush are present, to some extent, across the MLRA.

### LRU notes

LRU 01 Climatic Subset B Central Concept:

- Moisture Regime: Ustic
- Temperature Regime: Frigid
- Dominant Cover: rangeland (mixed grassland and sagebrush steppe)
- Representative Value (RV) of range of Effective Precipitation: 15-19 inches
- Representative Value (RV) of range of Frost Free Days: 90-110 days

The Subset B is primarily located in Madison, Gallatin, Park, and Meagher Counties of Southwest Montana.

### Classification relationships

Mueggler and Stewart. 1980. Grassland and Shrubland habitat types of Western Montana

1. *Stipa comata/Bouteloua gracilis* h.t.
2. *Agropyron spicatum/Bouteloua gracilis* h.t.

Montana Natural Heritage Program Vegetation Classification  
 1. *Stipa comata - Bouteloua gracilis* Herbaceous Vegetation  
 (STICOM – BOUGRA) Needle-and-thread/Blue grama  
 Natural Heritage Conservation Rank-G5 / S5  
 Edition / Author- 99-11-16 / S.V. Cooper,

EPA Ecoregions of Montana, Second Edition:  
 Level I: Northwestern Forested Mountains  
 Level II: Western Cordillera  
 Level III: Middle Rockies & Northern Great Plains  
 Level IV: Paradise Valley  
 Townsend Basin  
 Dry Intermontane Sagebrush Valleys

Level I: Great Plains  
 Level II: West-Central Semi-Arid Prairies  
 Level III: Northwestern Great Plains  
 Level IV: Shield-Smith Valleys  
 Non-calcareous Foothill Grassland

**Ecological site concept**

Site does not receive any additional water

- Soils are
  - o Not saline or saline-sodic.
  - o Shallow (10-20 inches deep to bedrock, lithic, or paralithic root restrictive layer).
  - o Not strongly or violently effervescent (calcareous) in the surface mineral 4 inches.
  - o Not skeletal within 10-20 inches of soil surface (averages less than 35 percent rock fragments in the 10-20 inch layer).
  - o Clay content greater than 32 percent in surface mineral 4 inch (ribbon length greater than 2 inches long).
- Parent material is colluvium and residuum from sedimentary rock

**Associated sites**

EX044B01B136	<b>Shallow Loamy (SwLo) LRU 01 Subset B</b> Shallow Loamy ecological site is often a nearby site and shares landscape position
EX044B01B038	<b>Droughty Steep (DrStp) LRU 01 Subset B</b> Droughty Steep ecological site is often below this site on the landscape.

**Similar sites**

EX044B01B138	<b>Shallow Droughty (SwDr) LRU 01 Subset B</b> The Shallow Droughty ecological site shares a similar plant community. The Shallow Droughty site does not have a high clay content and had a high rock fragment content in the soil which reduces the water holding capacity.
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**Table 1. Dominant plant species**

Tree	Not specified
Shrub	(1) <i>Artemisia tridentata ssp. wyomingensis</i> (2) <i>Rhus aromatica</i>
Herbaceous	(1) <i>Festuca campestris</i> (2) <i>Pseudoroegneria spicata</i>

## Legacy ID

R044BB131MT

### Physiographic features

This ecological site can occur on nearly level to very steep uplands. It often occurs in complexes with other ecological sites, particularly in rougher terrain. This site occurs on all slopes and exposures, and the aspect sometimes becomes significant. Slight variations in plant community composition and production can result due to aspect. The amount of exposed rock outcrop tends to increase as slopes increase. Runoff and the potential for water erosion can be important features of this site.

**Table 2. Representative physiographic features**

Hillslope profile	(1) Summit (2) Shoulder
Landforms	(1) Intermontane basin > Escarpment (2) Intermontane basin > Hillside or mountainside (3) Intermontane basin > Knoll
Runoff class	Medium to high
Elevation	1,463–1,768 m
Slope	2–15%

### Climatic features

The Central Rocky Mountain Valleys MLRA has a continental climate. 50 to 60 percent of the annual long-term average total precipitation falls between May and August. Most of the precipitation in the winter is snow on frozen ground. Average precipitation for LRU 01 Subset B is 17 inches, and the frost-free period averages 95 days. Precipitation is highest in May and June.

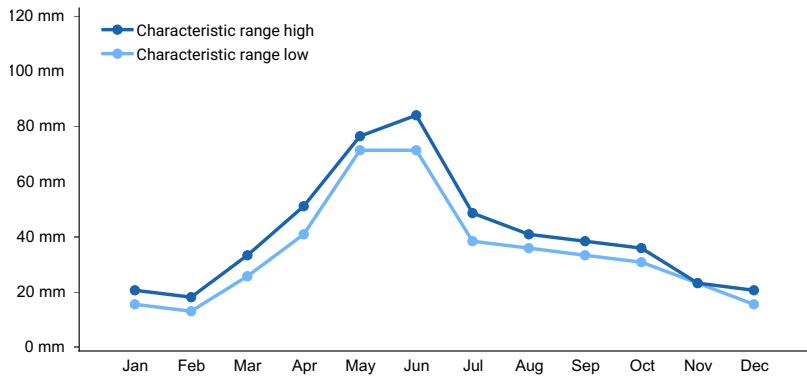
See Climatic Data Sheet for more details (Section II of the Field Office Technical Guide:

[http://efotg.nrcs.usda.gov/efotg\\_locator.aspx?map=MT](http://efotg.nrcs.usda.gov/efotg_locator.aspx?map=MT)) or reference the following climatic web site:

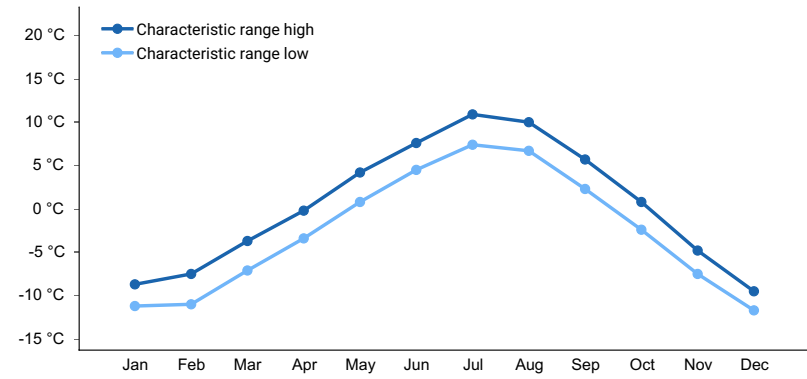
<http://www.wrcc.dri.edu/climsum.html>

**Table 3. Representative climatic features**

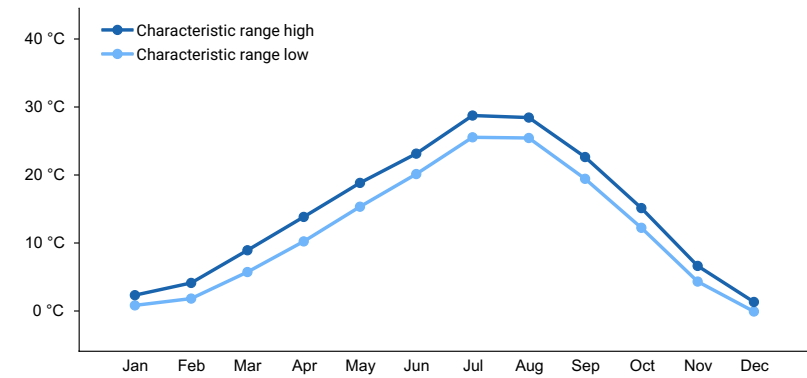
Frost-free period (characteristic range)	90-110 days
Freeze-free period (characteristic range)	96-123 days
Precipitation total (characteristic range)	356-483 mm
Frost-free period (actual range)	90-110 days
Freeze-free period (actual range)	82-136 days
Precipitation total (actual range)	356-483 mm
Frost-free period (average)	95 days
Freeze-free period (average)	108 days
Precipitation total (average)	432 mm



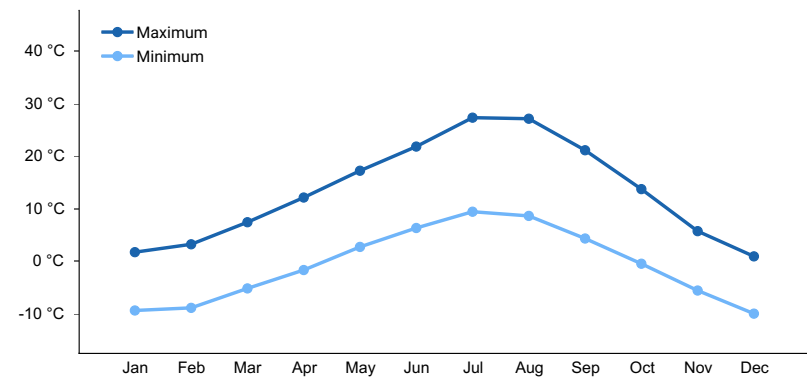
**Figure 1. Monthly precipitation range**



**Figure 2. Monthly minimum temperature range**



**Figure 3. Monthly maximum temperature range**



**Figure 4. Monthly average minimum and maximum temperature**

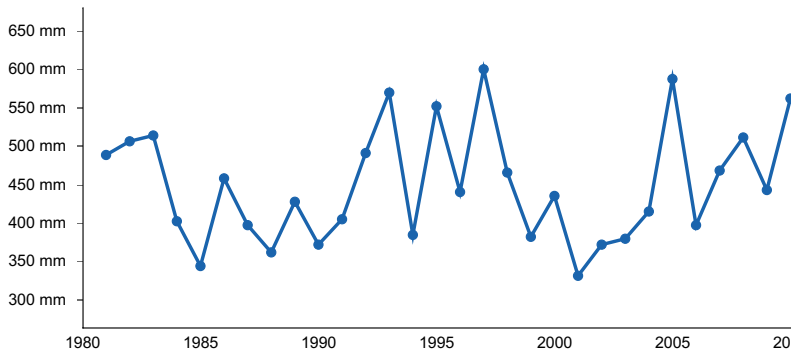


Figure 5. Annual precipitation pattern

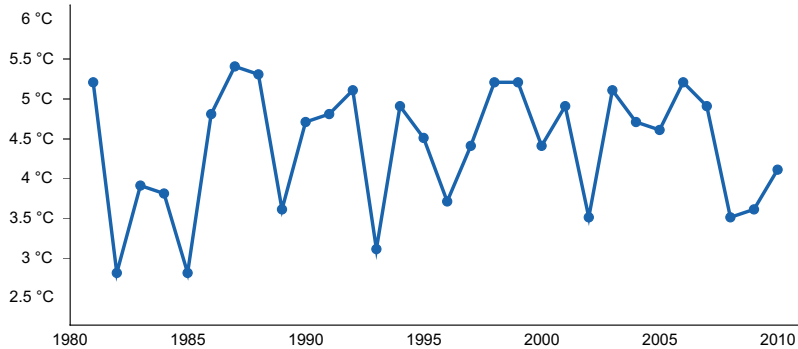


Figure 6. Annual average temperature pattern

### Climate stations used

- (1) WILSALL 8 ENE [USC00249023], Wilsall, MT
- (2) BOZEMAN 6 W EXP FARM [USC00241047], Bozeman, MT
- (3) NORRIS MADISON PH [USC00246157], Ennis, MT
- (4) MILLEGAN 14 SE [USC00245712], White Sulphur Springs, MT
- (5) LENNEP 5 SW [USC00244954], White Sulphur Springs, MT

### Influencing water features

Site is not associated with water features.

### Wetland description

Site is not associated with wetlands.

### Soil features

These are shallow clayey soils that are 10 to 20 inches deep and have underlying beds of decomposed shale or nearly impervious clays. These soils are formed from alluvium, slope alluvium, and residuum. The site is well drained with slow permeability. Typical soil surface texture is clay loam, with clay content in the top 4 inches of soil greater than 35 percent. The soil series present is almost exclusively Wilsall.

Table 4. Representative soil features

Parent material	(1) Colluvium–sedimentary rock (2) Residuum–sedimentary rock
Surface texture	(1) Clay loam
Family particle size	(1) Fine
Drainage class	Well drained

Permeability class	Slow
Depth to restrictive layer	51 cm
Soil depth	51 cm
Surface fragment cover <=3"	0–5%
Surface fragment cover >3"	0–5%
Available water capacity (0-50.8cm)	5.33–6.6 cm
Soil reaction (1:1 water) (0-50.8cm)	6.6–7.8
Subsurface fragment volume <=3" (25.4-50.8cm)	0–5%
Subsurface fragment volume >3" (25.4-50.8cm)	0–3%

## Ecological dynamics

The reference plant community is dominated by rough fescue (*Festuca campestris*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and western wheatgrass (*Pascopyrum smithii*). Subdominant species may include green needlegrass (*Nassella viridula*), Idaho fescue (*Festuca idahoensis*), needle and thread (*Hesperostipa comata*), Wyoming big sage (*Artemisia tridentata* ssp. *wyomingensis*), sumac (*Rhus* spp.), and winterfat (*Krascheninnikovia lanata*). In the reference state, up to two stems per acre of coniferous tree may exist on the landscape, but the core concept of the Reference State is to express no trees.

Wyoming big sagebrush steppe communities historically had low fuel loadings and were characterized by 10- to 70-year interval fires that produced a mosaic of burned and unburned lands (Bunting et al., 1987). A shift to the dominance of shrubs may occur in response to improper grazing management, drought, or where big sagebrush occurs due to a lack of fire. Shrub encroachment by a variety of species, including broom snakeweed (*Gutierrezia sarothrae*), fringed sagewort (*Artemisia frigida*), Wyoming big sagebrush, rubber rabbitbrush (*Ericameria nauseosa*), yellow rabbitbrush (*Chrysothamnus viscidiflorus*), antelope bitterbrush (*Purshia tridentata*), and plains prickly pear (*Opuntia polyacantha*), occurs within this site as the mid-statured bunchgrasses decrease. Shrub dominance and grass loss can be associated with soil erosion and, ultimately, thinning of the native soil surface. Subsequent loss of soil could lead to a Degraded State. All states could also lead to the Invaded State when there is a lack of weed prevention and control measures.

Historical records indicate that, prior to the introduction of livestock (cattle and sheep) during the late 1800s, elk and bison grazed this ecological site. Due to the nomadic nature and herd structure of bison, areas that were grazed received periodic, high-intensity, short-duration grazing pressure. The gold boom in the 1860s brought the first herds of livestock overland from Texas, and homesteaders began settling the area. During this time, cattle were the primary domestic grazers in the area. In the 1890s, Montana sheep production began to increase (a greater than 400 percent increase) and dominated the livestock industry until the 1930s. Since the 1930s, cattle production has dominated the livestock industry in the region (Wyckoff and Hansen 2001).

Natural fire was a major ecological driver of this entire ecological site. Fire tended to restrict tree and sagebrush growth to small patches and promote an herbaceous plant community. The natural fire return interval was highly variable, ranging up to 100 years; however, it was likely shorter than 35 years (Arno and Gruell 1983). With the historically recent, since 1910, suppression of fire sagebrush and trees has increased significantly.

Some of the major invasive species that can occur on this site include (but are not limited to) spotted knapweed (*Centaurea stoebe*), leafy spurge (*Euphorbia esula*), cheatgrass (*Bromus tectorum*), field brome (*Bromus arevensis*), yellow toadflax (*Linaria vulgaris*), and dandelion (*Taraxicum* spp.). Invasive weeds are beginning to have a high impact on this ecological site.

## Plant Communities and Transitions

A state and transition model for this ecological site is depicted below. Thorough descriptions of each state, transition, plant community, and pathway follow the model. This model is based on available experimental research,

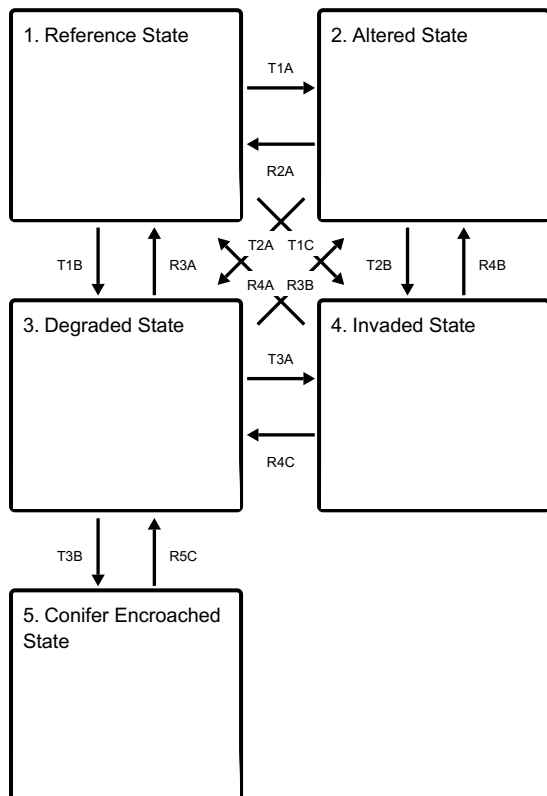
field data, field observations, and interpretations by experts. It is likely to change as knowledge increases.

The plant communities within the same ecological site will differ across the MLRA due to the naturally occurring variability in weather, soils, and aspect. The biological processes on this site are complex; therefore, representative values are presented in a land management context. The species lists are representative and are not botanical descriptions of all species occurring, or potentially occurring, on this site. They are intended to cover the core species and the known range of conditions and responses.

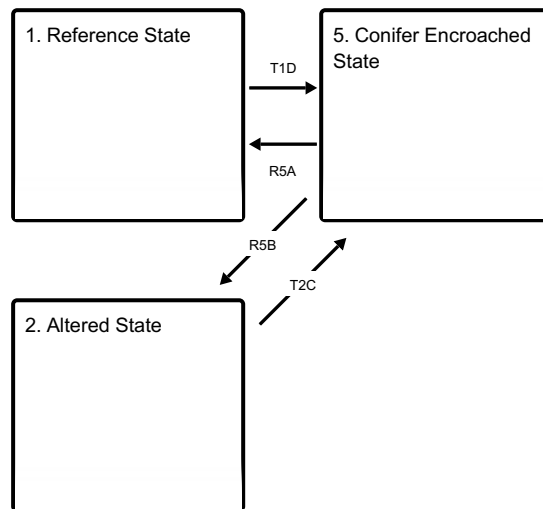
Although there is considerable qualitative experience supporting the pathways and transitions within the state and transition model (STM), no quantitative information exists that specifically identifies threshold parameters between grassland types and invaded types in this ecological site. For information on STMs, see the following citations: Bestelmeyer et al. (2003), Bestelmeyer et al. (2004), Bestelmeyer and Brown (2005), Stringham et al. (2003).

## State and transition model

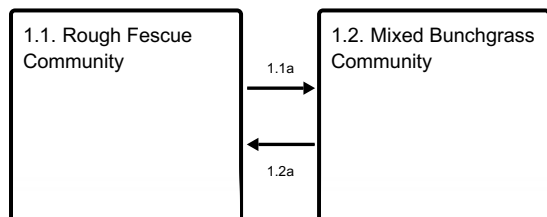
### Ecosystem states



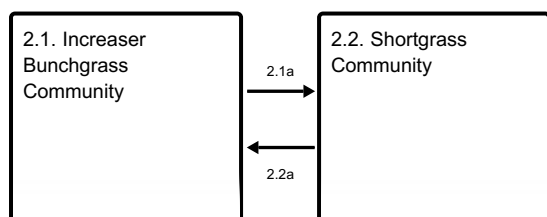
### States 1, 5 and 2 (additional transitions)



### State 1 submodel, plant communities



### State 2 submodel, plant communities



### State 3 submodel, plant communities

3.1. Shrub/Shortgrass  
Community

### State 4 submodel, plant communities

4.1. Invaded  
Community

### State 5 submodel, plant communities

5.1. Conifer  
Encroachment  
Community

## State 1 Reference State

The Reference State of this ecological site consists of two (2) potential plant communities: the Rough Fescue Community and the Mixed Bunchgrass Community. These are described below but are generally characterized by a mid-statured, cool-season grass community with limited shrub production. Community 1.1 is dominated by rough fescue and is considered the reference, while Community 1.2 has a codominance of rough fescue, bluebunch wheatgrass, green needlegrass, and western wheatgrass with a slight increase in shrubs. Infrequent fire maintained big sagebrush communities as open, treeless, seral stands of productive herbaceous species with patches of big sagebrush. As a result, the Reference State's core concept does not include coniferous trees; however, up to two (2) trees may exist on the landscape when closely situated to forested areas.

### Community 1.1 Rough Fescue Community

In the Rough Fescue Community, rough fescue, bluebunch wheatgrass, and western wheatgrass are typically dominant. Green needlegrass, Idaho fescue, and winterfat are subordinates in the community. Shrub species (big sagebrush, fringed sagewort, and broom snakeweed) remain a minor part of the community. Spineless horsebrush (*Tetradymia canescens*) may occupy a small niche. Sandberg bluegrass (*Poa secunda*) and dryland sedges are also common. This state occurs on the Shallow Clay site in areas with proper livestock grazing or in areas with little or no grazing pressure. Careful grazing management of this ecological site is necessary to maintain this deep-rooted bunchgrass community. Rough fescue tends to respond negatively to summer grazing (King et al., 1998), regardless of grazing intensity (Dormaer and Willms, 1998). Bluebunch wheatgrass lacks resistance to grazing during the critical growing season (spring) and will decline in vigor and production if grazed in the critical growing season more than one year in three (Wilson et al., 1960). This evidence suggests that fall and dormant grazing in this community are most appropriate. The Reference State is moderately resilient and will return to dynamic equilibrium following a relatively short period of stress (such as drought or short-term improper grazing), provided a return of favorable or normal growing conditions and properly managed grazing. As discussed in the Ecological Dynamics section, the natural fire regime restricted shrubs and coniferous trees to relatively small portions of Reference Plant Community 1.1. Shrub species present may include Wyoming big sagebrush, spineless horsebrush, winterfat, tarragon (*Artemisia drucunculus*), and fringed sagewort. Infrequent fire probably maintained big sagebrush communities as open, treeless, seral stands of productive herbaceous species with patches of big sagebrush.



## Dominant plant species

- ponderosa pine (*Pinus ponderosa* var. *scopulorum*), tree
- Rocky Mountain juniper (*Juniperus scopulorum*), tree
- Douglas-fir (*Pseudotsuga menziesii*), tree
- big sagebrush (*Artemisia tridentata*), shrub
- common snowberry (*Symphoricarpos albus*), shrub
- Woods' rose (*Rosa woodsii*), shrub
- currant (*Ribes*), shrub
- rough fescue (*Festuca campestris*), grass
- bluebunch wheatgrass (*Pseudoroegneria spicata*), grass
- green needlegrass (*Nassella viridula*), grass
- needle and thread (*Hesperostipa comata*), grass
- lupine (*Lupinus*), other herbaceous
- American vetch (*Vicia americana*), other herbaceous
- arrowleaf balsamroot (*Balsamorhiza sagittata*), other herbaceous

Table 5. Annual production by plant type

Plant Type	Low (Kg/Hectare)	Representative Value (Kg/Hectare)	High (Kg/Hectare)
Grass/Grasslike	729	925	1149
Shrub/Vine	45	95	168
Forb	45	95	168
Tree	–	–	11
<b>Total</b>	<b>819</b>	<b>1115</b>	<b>1496</b>

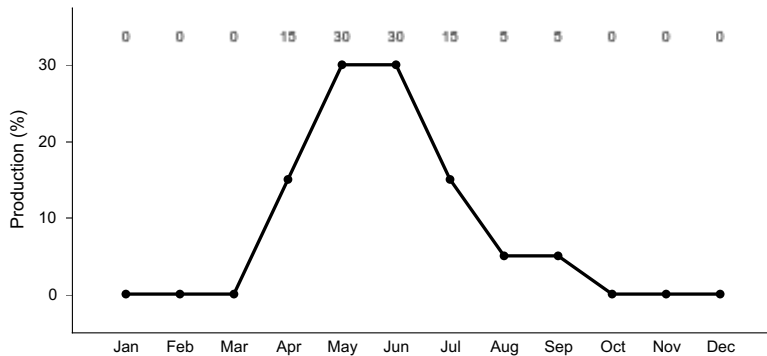
Table 6. Ground cover

Tree foliar cover	0%
Shrub/vine/liana foliar cover	15-25%
Grass/grasslike foliar cover	45-65%
Forb foliar cover	5-10%
Non-vascular plants	0-1%
Biological crusts	3-5%
Litter	35-40%
Surface fragments >0.25" and <=3"	0-15%
Surface fragments >3"	0-3%
Bedrock	0%
Water	0%
Bare ground	5-10%

Table 7. Soil surface cover

Tree basal cover	0%
Shrub/vine/liana basal cover	2-5%
Grass/grasslike basal cover	15-20%
Forb basal cover	3-8%
Non-vascular plants	0-1%
Biological crusts	3-5%
Litter	35-40%

Surface fragments >0.25" and <=3"	0-15%
Surface fragments >3"	0-3%
Bedrock	0%
Water	0%
Bare ground	5-10%



**Figure 8. Plant community growth curve (percent production by month). MT44B032, Dry Uplands. Cool season grass dominated system. Most dry, upland sites located within MLRA 44B LRU A are characterized by early season growth which is mostly complete by Mid-July. Limited fall "green-up" if conditions allow..**

## Community 1.2 Mixed Bunchgrass Community

With proper grazing management over time, the Mixed Bunchgrass Community (1.2) can return to the diversity and complexity of the Rough Fescue Community (1.1). Western wheatgrass and needle and thread tolerate grazing pressure better than bluebunch wheatgrass and rough fescue. The growing points of the present tall, deep-rooted bunchgrasses are several inches above the ground, making them very susceptible to continued close grazing (Smoliack et al., 2006), while those of western wheatgrass and needle and thread tend to be near the plant base. These plants increase in composition when less palatable and less grazing-tolerant plants decrease due to improper grazing management. Bluebunch wheatgrass, rough fescue, and western wheatgrass share dominance in the Mixed Bunchgrass Community (1.2). Other grass species, which are more tolerant to grazing and are likely to increase in number compared to the Rough Fescue Community, include Sandberg bluegrass (*Poa secunda*), prairie Junegrass, and blue grama (*Bouteloua gracilis*). Some increaser forb species include western yarrow, spiny phlox (*Phlox hoodii*), scarlet globemallow (*Sphaeralcea coccinea*), hairy goldenaster (*Heterotheca villosa*), and pussytoes (*Antennaria* spp.). Fringed sagewort (*Artemisia frigida*) is a shrub that also increases under prolonged drought or heavy grazing and can respond to precipitation that falls in July and August. Heavy, continuous grazing will reduce plant cover, litter, and mulch. The timing of grazing is important on this site because of the moisture limitations beyond June, especially on the drier sites. Bare ground will increase, exposing the soil to erosion. Litter and mulch will be reduced as plant cover declines. As long as the production of rough fescue and bluebunch wheatgrass remains a significant portion of the total biomass production, the site can return to the Rough Fescue Community (Pathway 1.2A) under proper grazing management and favorable growing conditions. Rough fescue will continue to decrease, and bluebunch wheatgrass will decrease slightly, while needle and thread and Idaho fescue increase until grass species composition is nearly equal. Once rough fescue has been reduced to less than 10 percent by weight, it may be difficult for the site to recover to Rough Fescue Community (1.1). The risk of soil erosion increases when canopy cover decreases below 50 percent. As soil conditions degrade, there will be a loss of organic matter, reduced litter, and reduced soil fertility. Degraded soil conditions increase the difficulty of reestablishing rough fescue and returning to the Rough Fescue Community (1.1). The Mixed Bunchgrass Community (1.2) is the at-risk plant community for this ecological site. When overgrazing continues, increaser species such as western wheatgrass, needle and thread, and native forb species will become more dominant, and this triggers the change to the Altered State (2) or the Degraded State (3). Until the Mixed Bunchgrass Community (1.2) crosses the threshold into another state, this community can be managed toward the Rough Fescue Community (1.1) using prescribed grazing and strategic weed control (if present). It may take several years to achieve this recovery, depending on growing conditions, the vigor of remnant rough fescue and bluebunch wheatgrass plants, and the aggressiveness of the weed treatments. Grazing management that benefits rough

fescue tends to be a deferred or rest rotation (Fleenor, July 2011).

### **Pathway 1.1a**

#### **Community 1.1 to 1.2**

Rough fescue and bluebunch wheatgrass lose vigor with improper grazing or extended drought. When vigor declines enough for plants to die or become smaller, species with higher grazing tolerance increase in vigor and production as they access the resources previously used by deep rooted bunchgrass. Decrease of species composition by weight of rough fescue to 50 percent of the grass community indicates that the plant community has shifted to the Mixed Bunchgrass Community (1.2). The driver for community shift 1.1A is improper grazing management or prolonged drought. This shift is triggered by the loss of vigor of rough fescue, soil erosion or prolonged drought coupled with improper grazing. Blaisdell (1958) stated that drought and warmer than normal temperatures are known to advance plant phenology by as much as one month. During drought years, plants may be especially sensitive or in a critical stage of development earlier than expected.

### **Pathway 1.2a**

#### **Community 1.2 to 1.1**

The Mixed Bunchgrass Community (1.2) will return to the Rough Fescue Community (1.1) with proper grazing management and appropriate grazing intensity. Favorable moisture conditions will facilitate or accelerate this transition. It may take several years of favorable conditions for the community to transition back to a rough fescue dominated state. The driver for this community shift (1.2A) is increased vigor of rough fescue to the point that it represents more than 50 percent by weight of the grass community. The trigger for this shift is the change in grazing management favoring rough fescue. In general, conservative grazing management styles such as deferred or rest rotations utilizing light to moderate grazing (less than 50 percent use) coupled with favorable growing conditions like cool, wet springs are these triggers. These systems tend to promote increases in soil organic matter which promotes microfauna and can increase infiltration rates. Inversely, long periods of rest at a time when this state is considered to be stable may not result in an increase in rough fescue and it has been suggested (Noy-Meir 1975) that these long periods of rest or underutilization may actually drive the system to a lower level of stability by creating large amounts of standing biomass, dead plant caudex centers, and gaps in the plant canopy.

## **State 2**

### **Altered State**

This state is characterized by having less than 10 percent rough fescue by dry weight. This state is represented by two communities. Community 2.1 is a community dominated by Idaho fescue and needle and thread with small components of deep-rooted bunchgrasses such as rough fescue, bluebunch wheatgrass, and green needlegrass. Community 2.2 has a significantly reduced deep-rooted bunchgrass population that is restricted to protected areas under shrubs. Production in this state tends to be significantly lower than in the Reference State (1). Some native plants tend to increase under prolonged drought and/or heavy grazing practices. A few of these species may include western wheatgrass, needle and thread, Sandberg bluegrass, scarlet globemallow, hairy goldenaster, and fringed sagewort.

### **Community 2.1**

#### **Increaser Bunchgrass Community**

Long-term grazing mismanagement with continuous growing-season pressure will reduce the total productivity of the site and lead to an increase in bare ground. Once plant cover is reduced, the site is more susceptible to erosion and degradation of soil properties. Soil erosion or reduced soil health will result in reduced plant production. This soil erosion or loss of soil fertility indicates the transition to the Altered State (2) because it creates a threshold requiring energy input to return to the Reference State (1). Transition to the Increaser Bunchgrass Community (2.1) may be exacerbated by extended drought conditions. Needle and thread and western wheatgrass dominate this community (2.1). Rough fescue and bluebunch wheatgrass make up less than 10 percent of species composition by dry weight, and the remaining deep-rooted bunchgrass plants tend to be scattered and low in vigor. Increaser and invader species will be more common and create more competition for deep-rooted bunchgrass. This makes it difficult for them to quickly respond to a change in grazing management alone. Therefore, an input of energy is required for the community to return to the Reference State (1). Wind and water erosion may be eroding soil from

the plant interspaces. Soil fertility is reduced, and soil surface erosion resistance has declined compared to the Reference State (1). This community crossed a threshold compared to the Mixed Bunchgrass Community (1.2) due to the erosion of soil, vegetation composition, loss of soil fertility, or degradation of soil conditions. This results in a critical shift in the ecology of the site. The effects of soil erosion can alter the hydrology, soil chemistry, soil microorganisms, and soil structure to the point where intensive restoration is required to restore the site to another state or community. Changing grazing management alone cannot create sufficient improvement to restore the site within a reasonable time frame. Dormaar (1997) stated that with decreased grazing pressure, a needle and thread/blue grama plant community did not change species composition, but the content of the soil carbon increased. It will require a considerable input of energy to move the site back to the Reference State (1). This state has lost soil or vegetation attributes to the point that recovery to the Reference State (1) will require reclamation efforts, i.e., soil rebuilding, intensive mechanical treatments, and/or reseeding. The transition to this state could result from overgrazing, especially repeated early-season grazing coupled with extensive drought. If heavy grazing continues, plant cover, litter, and mulch will continue to decrease, and bare ground will increase, exposing the soil to accelerated erosion. Litter and mulch will move off-site as plant cover declines. The Increaser Bunchgrass Community will then shift to the Shortgrass Community (2.2) or the Degraded State (3.3), depending on the level of disturbance. Introduction or expansion of invasive species will further drive the plant community into the Invaded State (4).

## **Community 2.2 Shortgrass Community**

With continued mismanagement of grazing, especially coupled with prolonged drought, needle and thread will decrease in vigor. The bunchgrasses will decline in production as plants die or become smaller, and species with higher grazing tolerance (such as western wheatgrass) will increase in vigor and production as they respond to resources previously used by the bunchgrasses. These less desirable, shorter-rooted species will become dominant in this community with midstatured bunchgrasses such as needle and thread and Idaho fescue. Shrubs will become more competitive for limited moisture as bare ground and soil erosion increase. Remaining deep rooted bunchgrasses such as rough fescue and bluebunch wheatgrass are nearly absent in this community; however, remnant populations may exist under shrub canopy away from grazing pressure.

### **Pathway 2.1a Community 2.1 to 2.2**

The driver for community shift 2.1a is continued improper grazing management. This shift is triggered by the continued loss of bunchgrass vigor, especially the remaining trace amounts of rough fescue and bluebunch on the site. Shrubs will protect these less vigorous bunchgrasses. The mid- and short-statured grasses will become more competitive and will become co-dominant with the bunchgrasses. Shrubs will increase their canopy cover but stay at about 15 percent.

### **Pathway 2.2a Community 2.2 to 2.1**

If proper grazing management is implemented, needle and thread may regain its vigor and move towards the Increaser Bunchgrass Community (2.1). This will give grasses an advantage over invading shrubs before too much competition takes place. The advantage to grasses comes from following a conservative grazing plan where utilization is reduced and rest or deferment is incorporated since the transition from Plant Community 2.1 to Plant Community 2.2 is likely caused by repeated heavy utilization. Van Poolen and Lacey (1979) found that forage production increased by an average of 35 percent on western ranges when converting heavy to moderate utilization (less than 50 percent). Shrub removal and favorable growing conditions can accelerate this process. If the site contains Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis*), low-intensity fire or mechanical treatment (Wambolt 1986) could reduce shrub competition and allow for increased vigor and the reestablishment of grass species.

## **State 3 Degraded State**

Degraded State lacks midstatured bunchgrasses. Sandberg bluegrass and prairie Junegrass are dominant grasses,

and increase shrubs nearly replace larger shrub species. Remaining larger shrub species are heavily hedged. Likely a terminal state (e.g., restoration will likely be impossible or unsuccessful and require major energy inputs).

**Characteristics and indicators.** increased bare ground (excess of 25 percent) annual grasses common complete removal of deep rooted tall bunchgrasses and replaced with sandberg bluegrass, western wheatgrass, and blue grama sagebrush nearly gone and replaced with cactus rabbitbrush and broom snakeweed

### **Community 3.1 Shrub/Shortgrass Community**

Soil loss continues, and subsequent losses of soil organic matter create conditions where native perennial grasses are reduced to less than 50 percent of their total production. Grass and forb cover may be very sparse or clumped (canopy coverage less than 30 percent). Weeds, annual species, and shrubs dominate the plant community. Mid-stature perennial bunchgrass species (e.g., needle and thread) may exist, but only in small patches. This could occur due to overgrazing (failure to adjust stocking rates to declining forage production due to increased invasive dominance), a long-term lack of fire (if Wyoming big sagebrush occurs), or the introduction of invasive species. In the most severe stages of degradation, there is a significant amount of bare ground, and large gaps occur between plants. Potential exists for soils to erode to the point that irreversible damage may occur. This is a critical shift in the ecology of the site. Soil erosion combined with a lack of organic matter deposition due to sparse vegetation creates changes to the hydrology, soil chemistry, soil microorganisms, and soil structure to the point where intensive restoration is required to restore the site to another state or community. Changing management (i.e., improving grazing management) cannot create sufficient change to restore the site within a reasonable time frame. This state is characterized by soil surface degradation and little plant soil surface cover. The forb component changes to being dominated by spiny phlox (*Phlox hoodii*), and shrub canopy cover is usually greater than 20 percent. Big sagebrush is replaced with a dominant community of broom snakeweed, rubber rabbitbrush, fringed sagewort, and plains prickly pear cactus. This state has lost soil or vegetation attributes to the point that recovery to the Reference State will require reclamation efforts, i.e., soil rebuilding, intensive mechanical treatments, and/or reseeding. This plant community may be in a terminal state and will not return to the reference state because of degraded soil conditions and the loss of higher successional native plant species. Key factors in the approach to transition include: a decrease in grass canopy cover and production; an increase in shrub canopy cover; increases in mean bare patch size, increases in soil crusting; decreases in the cover of cryptobiotic crusts, decreases in soil aggregate stability; and/or evidence of erosion, including water flow patterns and litter movement.

### **State 4 Invaded State**

The Invaded State is identified as being in the exponential growth phase of invader abundance where control is a priority. Dominance (or relative dominance) of noxious or invasive species reduces species diversity, forage production, wildlife habitat, and site protection. A level of 15 percent invasive species composition by dry weight indicates that a substantial energy input will be required to create a shift to the grassland state (herbicide, mechanical treatment), even with a return to proper grazing management or favorable growing conditions. Prescriptive grazing can be used to manage invasive species. In some instances, carefully targeted grazing (sometimes in combination with other treatments) can reduce or maintain the species composition of invasive species. These communities within this state will follow a pathway if the invasive or noxious species continue to thrive without mechanical, biological, or chemical control methods to exceed 50 percent of species composition by dry weight. The invasive nature of the weed outcompetes the present plant community. Once the weed reaches its maximum population level for this site, effective control is unlikely without massive resource inputs. Ecological processes at the site may change after invading species have established and spread (Walker and Smith 1997).

### **Community 4.1 Invaded Community**

Communities in this state may be structurally indistinguishable from the Reference State except that invasive or noxious species exceed 15 percent of species composition by dry weight. This state may also include a community similar to the Degraded State (3) except that invasive or noxious species exceed 15 percent of species composition by dry weight. Although there is no research to document the level of 15 percent, this is estimated to be the point in the invasion process following the lag phase based on the interpretation of Masters and Sheley (2001). For aggressive invasive species (i.e., spotted knapweed), a 15 percent threshold could be less than 10 percent. Early in

the invasion process, there is a lag phase where the invasive plant populations remain small and localized for long periods before expanding exponentially (Hobbs and Humphries 1995). Production in the invaded community may vary greatly. A site dominated by Kentucky bluegrass or spotted knapweed, where soil fertility and chemistry remain near reference, may have production near that of the reference community. A site with degraded soils and an infestation of cheatgrass may produce only 10 to 20 percent of the reference community. Once invasive species dominate the site, either in species composition by weight or in their impact on the community, the threshold has been crossed to the Invaded State (4). As invasive species such as spotted knapweed, cheatgrass, and leafy spurge become established, they become very difficult to eradicate. Therefore, considerable effort should be put into preventing plant communities from crossing a threshold into the Invaded State (4) through early detection and proper management. Preventing new invasions is by far the most cost-effective control strategy and typically places an emphasis on education. Control measures used on the noxious plant species impacting this ecological site include chemical, biological, and cultural control methods. The best success has been found with an integrated pest management (IPM) strategy that incorporates one or several of these options along with education and prevention efforts (DiTomaso 2000).

## **State 5 Conifer Encroached State**

Rocky Mountain juniper (*Juniperus scopulorum*), Douglas fir (*Pseudotsuga menziesii*), and ponderosa pine (*Pinus ponderosa*) encroachment is limited on this ecological site and is generally focused in areas where the mountains of MLRA 44B transition quickly to MLRA 43B. Under the Reference State, up to two (2) stem per acres of conifers may exist as part of long-term fire suppression; however the core concept of this ecological site is to express no coniferous trees. Conifer Encroached State consists of up to 4 potential phases. The Early Phase, Mid Phase, Late Phase, and Closed Phase are defined by the amount of encroachment and age class of the stand. This state typically occurs in response to a combination of long-term fire suppression, grazing history, and increased atmospheric carbon dioxide. The trigger for transition is a coniferous expansion of more than 2 stems per acre

### **Community 5.1 Conifer Encroachment Community**

Rocky Mountain juniper (*Juniperus scopulorum*), ponderosa pine (*Pinus ponderosa*), and Douglas fir (*Pseudotsuga menziesii*) encroachment is common on this ecological site and is generally focused in areas where the mountains of MLRA 44B transition quickly to MLRA 43B. Under the Reference State, no conifers should exist on this site. It is also noted that all states may transition to the Conifer Encroached State; however, encroachment is most likely to occur in the Altered State, where there is an increase in bare ground due to a combination of factors that allows seed-to-soil contact with reduced competition. Fire suppression and improper grazing management are the two most common triggers. The exact mode in which conifers begin to encroach varies; however, the trend points to a combination of 1 or more of the following: repeated moderately heavy to heavy grazing; reduced (non-existent) fire frequency; increased atmospheric carbon; and a generally warmer climate compared to that of pre-settlement. When heavy grazing occurs, areas in the plant canopy open, allowing for seed dispersal by bird or overland flow via rills on neighboring sites. The effects of conifer encroachment are not immediately noticeable, but over time, as the conifer canopy increases, light and water interception increase, which reduces opportunities for herbaceous plants. One paper (Barrett, 2007) suggests that for precipitation to penetrate the juniper canopy, events must be greater than 0.30 inches. Increased tree canopy creates perching sites for predators, which reduces site suitability for greater sage grouse. More information is needed on the full extent and impact of juniper encroachment on these plant communities for an approved ecological site description. Studies (Miller et al., 2000) based in an area similar to the Rocky Mountain juniper community of Montana suggest following a phased approach to characterizing the juniper stand. Not unlike the western juniper community discussed in Miller et al., the Conifer Encroached Communities of Montana exhibit three or four different phases based, at this time, on qualitative experience. Phase I (Early) is defined by actively expanding conifer cover with generally less than 10 percent canopy cover and the tree limbs generally touching the ground. This early stage generally has not completely lost its hydrologic functions, but herbaceous plant communities may show signs of reduced production and species richness. Control methods include mechanical removal and prescribed fire. Prescribed fire is still effective in this phase as it still contains the necessary native plants for recovery. The tree canopy is also low enough that the risk of a dangerously hot fire is reduced. Phase II (Midphase) is still actively expanding, but canopy cover may reach 15 to 25 percent, and due to the more mature trees, seed production is very high. This Midphase begins to highly restrict herbaceous and shrubby plants, and junipers tend to be codominant. Hydrology is departing from reference, with rills becoming longer and, in isolated areas, erosional gullies possible. Control methods for the Midphase should focus on

mechanical treatment, as there is a high risk of catastrophic and potentially sterilizing fire. Phase III (Late Phase) is where conifer cover exceeds 25 percent and has slowed as a forest condition. Lower tree limbs begin to die, and the shrub cover is nearly gone. Traveling through this community is increasingly difficult. Conifers become the dominant plant, with herbaceous plant production greatly decreasing. Bare ground increases, and hydrologic function is nearly lost compared to a grass or shrub community. The late phase should focus more on restoration than control, as the necessary plants will likely not be present to cross the threshold back to a rangeland situation. Because soil stability and hydrologic function are lacking in this phase, mechanical juniper removal will be required. Phase IV (Closed Phase) is the steady state forest, where the system is nearly devoid of rangeland plants. The trees stop producing seed and begin to close in on each other. This phase is impassable, and nearly all light and precipitation are intercepted. Bare ground may be reduced due to excessive forest duff layer. As a result, soil chemistry slowly changes due to acidification from conifer needles. The closed phase is extremely rare in this LRU for two reasons. 1) This phase takes upwards of 100 years to occur and even under suppression, fire will control these sites 2) Management often occurs before trees are allowed to reach this phase. The presence of sagebrush stumps indicates that the historical plant community was rangeland, preventing the misclassification of historic coniferous forests (often more than 100 years old).

### **Transition T1A** **State 1 to 2**

The Reference State (1) transitions to the Altered State (2) if rough fescue, by dry weight, decreases to below 10 percent or if bare ground cover is increased beyond 20 percent. The driver for this transition is the loss of taller bunchgrasses, which creates open areas in the plant canopy with bare soil. Soil erosion results in decreased soil fertility, driving transitions to the Altered State. There are several other key factors signaling the approach of transition T1A: increases in soil physical crusting, decreases in cover of cryptogamic crusts, decreases in soil surface aggregate stability, and/or evidence of erosion including water flow patterns, development of plant pedestals, and litter movement. The trigger for this transition is improper grazing management and/or long-term drought, leading to a decrease in rough fescue composition to less than 10 percent and a reduction in total plant canopy cover.

### **Transition T1B** **State 1 to 3**

The Reference State (1) transitions to the Degraded State (3) when rough fescue and bluebunch wheatgrass are removed from the plant community and needle and thread is subdominant to short-statured bunchgrasses such as Sandberg bluegrass. This transition differs from T1A in that it is generally a rapid transition and usually associated with disturbances such as repeated overgrazing or heavy human traffic. This rapid transition is generally realized where livestock are confined to small pastures for long periods of time, such as horse pastures and calving lots. The driver for this transition is the loss of taller bunchgrasses, which creates openings in the canopy and exposes bare soil. Soil erosion results in decreased soil health, driving transitions to the Degraded State. There are several other key factors signaling the approach of transition T1B: increases in soil physical crusting, decreases in cover of cryptogamic crusts, decreases in soil surface aggregate stability, and/or evidence of erosion including water flow patterns, development of plant pedestals, and litter movement. The trigger for this transition is improper grazing management, long term drought, and/or heavy human disturbance.

### **Transition T1C** **State 1 to 4**

Healthy plant communities are most resistant to invasion. However, regardless of grazing management, without some form of active weed management (chemical, mechanical, or biological control) and prevention, the Reference State (1) can transition to the Invaded State (4) in the presence of aggressive invasive species such as spotted knapweed, leafy spurge, and cheatgrass. This will occur even if the reference community is thriving. The Central Rocky Mountain Valleys tend to resist invasion by cheatgrass; however, repeated heavy grazing or intense human activities can open the interspaces of the bunchgrass community and allow for encroachment. Long-term stress conditions for native species (e.g., overgrazing, drought, and fire) accelerate this transition. If populations of invasive species reach critical levels, the site transitions to the Invaded State. The trigger for this transition is the presence of aggressive invasive species. The species composition by dry weight of invasive species approaches 10 percent.

## **Transition T1D**

### **State 1 to 5**

The transition from the Reference State (1) to the Conifer Encroached State (5) is driven primarily by long-term fire suppression, but heavy grazing may contribute to increased bare ground for seeding sites. Encroachment occurs most quickly within 200 feet of the seed source. The trigger for transition is a conifer stem count greater than two (2) per acre.

## **Restoration pathway R2A**

### **State 2 to 1**

The Altered State (2) has lost soil or vegetation attributes to the point that recovery to the Reference State (1) will require reclamation efforts such as soil rebuilding, intensive mechanical and cultural treatments, and/or revegetation. Examples of mechanical treatment may be brush control while cultural treatments may include prescribed grazing, targeted brush browsing, or prescribed burning. Low intensity prescribed fires to reduce competitive increaser plants such as needle-and-thread and Sandberg bluegrass. A low intensity fire will also reduce Wyoming big sagebrush densities. In areas with potential of annual grass infestation, fire should be carefully planned or avoided. The drivers for this restoration pathway are reclamation efforts along with proper grazing management.

## **Transition T2A**

### **State 2 to 3**

As improper grazing management continues vigor of bunch grasses will decrease, and the shorter grasses and shrubs will increase towards the Degraded Shortgrass State (3). Prolonged drought will provide a competitive advantage to shrubs allowing them to become co-dominant with grasses. Shrub canopy will increase above 15 percent canopy cover. Key transition factors: increase of native shrub canopy cover; reduction in bunchgrass production; decrease in total plant canopy cover and production; increases in mean bare patch size; increases in soil crusting; decreases in cover of cryptobiotic crusts; decreases in soil aggregate stability; and/or evidence of erosion including water flow patterns and litter movement.

## **Transition T2B**

### **State 2 to 4**

Invasive species can occupy the Altered State (2) and drive it to the Invaded State (4). The Altered State is at risk if invasive seeds and/or other viable material are present. The driver for this transition is more than 10 percent dry weight of invasive species.

## **Transition T2C**

### **State 2 to 5**

The transition from the Altered State (2) to the Conifer Encroached State (5) is driven primarily by long-term fire suppression, but heavy grazing may contribute to increased bare ground for seeding sites. Encroachment occurs most quickly within 200 feet of the seed source. The trigger for transition is a conifer stem count greater than two (2) per acre.

## **Restoration pathway R3A**

### **State 3 to 1**

The Degraded State (3) has lost soil or vegetation attributes to the point that recovery to the Reference State (1) will require reclamation efforts, such as soil rebuilding, intensive mechanical treatments, and/or revegetation. Studies suggest (Whitford et al 1989) a mulch with high carbon to nitrogen ratio such as wood chips or bark in low moisture scenarios can be beneficial for slow mobilization of plant available nitrogen. Biochar may also be added to the system to improve Soil Organic Carbon (SOC) which should improve Cation Exchange Capacity (CEC), microbial activity, and hydrologic conductivity (Stavi 2012). The drivers for the restoration pathway are removal of increaser species, restoration of native bunchgrass species, persistent management of invasives and shrubs, and proper grazing management. Without continued control, invasive and shrub species are likely to return (probably rapidly)



due to presence of seeds and/or other viable material in the soil and management related increases soil disturbance.

### **Restoration pathway R3B**

#### **State 3 to 2**

Since the bunchgrass plant community has been significantly reduced, restoration to the Altered State (2) is unlikely unless a seed source is available. However, if a sufficient amount of grass remains on the site, chemical application and/or biological control in conjunction with proper grazing management, can reduce the amount of shrubs and invasive species and restore the site to the Shortgrass Community (2.2). Low intensity fire can be utilized to reduce Wyoming big sagebrush competition and allow the reestablishment of grass species. Caution must be used when considering fire as a management tool on sites with fire tolerant shrubs such as rubber rabbitbrush, as these shrubs will re-sprout after a burn. Broom snakeweed and fringed sagewort may or may not re-sprout depending on conditions (USDA Forest Service 2011).

### **Transition T3A**

#### **State 3 to 4**

Invasive species can occupy the Degraded State (3) and drive it to the Invaded State (4). The Degraded State is at risk of this transition occurring if invasive seeds or viable material are present. The driver for this transition is presence of critical population levels (more than 10 percent dry weight of invasive species). The trigger is the presence of seeds or viable material of invasive species. This state has sufficient bare ground that the transition could occur simply due to presence or introduction of invasive seeds or viable material. This is particularly true of aggressive invasive species such as spotted knapweed. This transition could be assisted by overgrazing (failure to adjust stocking rate to declining forage production), long-term lack of fire, or extensive drought.

### **Transition T3B**

#### **State 3 to 5**

The transition from the Degraded State (3) to the Conifer Encroached State (5) is driven primarily by heavy grazing; contributing to increased bare ground for seeding sites. Encroachment occurs most quickly within 200 feet of the seed source. The trigger for transition is a conifer stem count greater than two (2) per acre.

### **Restoration pathway R4A**

#### **State 4 to 1**

If invasive species are removed before remnant populations of bunchgrasses have been drastically reduced the Invaded State (4) can return to the Reference State. The driver for the reclamation pathway is weed management with reseeding. Continued Integrated Pest Management (IPM) will be required as many of the invasive species that can occupy the Invaded State have extended dormant seed life.

### **Restoration pathway R4B**

#### **State 4 to 2**

If invasive species are removed before remnant populations of bunchgrasses have been drastically reduced the Invaded State (4) can return to the Altered State. The driver for the reclamation pathway is weed management with reseeding. Continued Integrated Pest Management (IPM) will be required as many of the invasive species that can occupy the Invaded State have extended dormant seed life.

### **Restoration pathway R4C**

#### **State 4 to 3**

If invasive species are removed before remnant populations of bunchgrasses have been drastically reduced the Invaded State (4) can return to the Degraded State. The driver for the reclamation pathway is weed management with reseeding. Continued Integrated Pest Management (IPM) will be required as many of the invasive species that can occupy the Invaded State have extended dormant seed life.

## **Restoration pathway R5A**

### **State 5 to 1**

Restoration efforts may simply focus on the removal of coniferous trees and shrubs to restore the Conifer Encroached State (5) to the Reference State (1), depending on the level of conifer canopy cover and its impact on rangeland health. If following and utilizing the phases established by Miller et al., management and restoration methods will vary. A majority of the conifer encroachment in MLRA 44B will fall into the early two phases of Miller's phases. When conifers are removed through brush management and/or prescribed fire, Phase I may reveal none-to-slight to moderate deviations from rangeland health. If mechanical removal of conifers is utilized, no grazing management is needed, assuming relatively conservative management had been used prior to treatment. If prescribed fire is utilized, short-term grazing deferment and/or rest are suggested. In a short period of time, removing a Phase I encroachment will return the site to its original state. Proactive pest management is encouraged. Phase II encroachment may require a more intensive mechanical removal of trees and shrubs, with prescribed fire not being a feasible method of control as this community may be at risk of catastrophic fire due to canopy density. Phase II displays a moderate departure from Reference, suggesting an overall instability of the site such as reduced herbaceous production, reduced functional/structural groups (e.g., reduced mid-statured bunchgrasses), increased rill frequency and length, and possibly more bare ground. Increased post-treatment grazing management may be necessary. Grazing management may be as simple as short-term growing season deferment; however, long-term rest may be necessary in the latter stages of Phase II encroachment. The latter stages of Phase II encroachment will likely require some short-term erosion mitigation, such as straw waddles, as well as range planting and/or critical area planting to re-establish any loss of native herbaceous plants, particularly mid-statured cool-season bunchgrasses. Phase III encroachment canopy cover resembles forested sites with larger trees and shrubs. Prior to any prescribed burning, forest management-style tree removal (removal of woody debris and logs from the site) will be required to prevent the fire from burning too hot. The result of a prescribed fire on this site is typically unknown as seed sources of native herbaceous plants are usually limited to small patches. Since the Shallow Clay ecological site for 44B LRU 01 Subset B is a dry site, herbaceous plants will likely have been depleted under a Phase III encroachment. This means there is an opportunity for large areas of bare ground, increased rilling, and, in some cases, gully erosion. Post-treatment will require range planting and/or critical area seeding, erosion control, pest management, and possibly soil carbon amendments (biochar). Grazing management (primarily rest) will be required to ensure the establishment of any new seedlings.

## **Restoration pathway R5B**

### **State 5 to 2**

The Conifer Encroached State (5) Phases I and II will generally resemble the Altered State (2) on this site. If following and utilizing the phases established by Miller et al., management and restoration methods will vary. A majority of the conifer encroachment in MLRA 44B will fall into the early two phases of Miller's phases. When conifers are removed through brush management and/or prescribed fire, Phase I may show none-to-slight to moderate deviations from rangeland health. If mechanical removal of conifers is utilized, no grazing management is needed, assuming relatively conservative management had been used prior to treatment. If prescribed fire is utilized, short-term grazing deferment and/or rest are suggested. In a short period of time, removing a Phase I encroachment will return the site to its original state. Proactive pest management is encouraged. Phase II encroachment may require a more intensive mechanical removal of trees and shrubs, with prescribed fire not being a feasible method of control as this community may be at risk of catastrophic fire due to canopy density. Phase II displays a moderate departure from Reference, suggesting an overall instability of the site such as reduced herbaceous production, reduced functional and structural groups (e.g., reduced mid-statured bunchgrasses), increased rill frequency and length, and possibly more bare ground. Increased post-treatment grazing management may be necessary. Grazing management may be as simple as short-term growing season deferment; however, long-term rest may be necessary in the latter stages of Phase II encroachment. The latter stages of Phase II encroachment will likely require some short-term erosion mitigation such as straw waddles as well as range planting and/or critical area planting to re-establish any loss of native herbaceous plants, particularly mid-statured cool-season bunchgrasses. Phase III encroachment canopy cover resembles forested sites with larger trees and shrubs. Prior to any prescribed burning, forest management-style tree removal (removal of woody debris and logs from the site) will be required to prevent the fire from burning too hot. The result of a prescribed fire on this site is typically unknown as seed sources of native herbaceous plants are usually limited to small patches. Since the Shallow Clay ecological site for 44B LRU 01 Subset B is a dry site, herbaceous plants will likely have been depleted under a Phase III encroachment. This means there is an opportunity for large areas of bare ground, increased rilling, and, in some cases, gully erosion. Post-treatment will require range planting and/or critical area seeding, erosion control,

pest management, and possibly soil carbon amendments (biochar). Grazing management (primarily rest) will be required to ensure the establishment of any new seedlings.

## Restoration pathway R5C

### State 5 to 3

The Conifer Encroached State (5) Phases II and III may resemble the Degraded State (3) on this site. If following and utilizing the phases established by Miller et al., management and restoration methods will vary. An overwhelming majority of the conifer encroachment in MLRA 44B will fall into the early two phases of Miller's phases. This restoration pathway is extremely rare because managing a degraded state is typically not cost-effective for land managers. When conifers are removed through brush management and/or prescribed fire, Phase I may show none-to-slight to moderate deviations from rangeland health. If mechanical removal of conifers is utilized, no grazing management is needed, assuming relatively conservative management had been used prior to treatment. If prescribed fire is utilized, short-term grazing deferment and/or rest are suggested. Given a short time removal of a Phase I encroachment will recover to Reference. Proactive pest management is encouraged. Phase II Encroachment may require a more intensive mechanical removal of trees and shrubs, with prescribed fire not being a feasible method of control as this community may be at risk of catastrophic fire due to canopy density. Phase II displays a moderate departure from Reference, suggesting an overall instability of the site such as reduced herbaceous production, reduced functional and structural groups (e.g., reduced mid-statured bunchgrasses), increased rill frequency and length, and possibly more bare ground. Increased post-treatment grazing management may be necessary. Grazing management may be as simple as short-term growing season deferment; however, long-term rest may be necessary in the latter stages of Phase II encroachment. The latter stages of Phase II encroachment will likely require some short-term erosion mitigation, such as straw waddles, as well as range planting and/or critical area planting to re-establish any loss of native herbaceous plants, particularly mid-statured cool-season bunchgrasses. Phase III Encroachment canopy cover resembles forested sites with larger trees and shrubs. Forest management style tree removal (woody debris and logs removed from the site) will be necessary prior to any prescribed burning as to prevent the fire from burning too hot. The results of a prescribed fire on this site are typically unknown as seed sources of native herbaceous plants are usually limited to small patches. Since the Shallow Clay ecological site for 44B LRU 01 Subset B is a dry site, herbaceous plants will likely have been depleted under a Phase III encroachment. This means there is an opportunity for large areas of bare ground, increased rills, and, in some cases, gully erosion. Post-treatment will require range planting and/or critical area seeding, erosion control, pest management, and possibly soil carbon amendments (biochar). Grazing management (primarily rest) will be required to ensure the establishment of any new seedlings.

## Additional community tables

Table 8. Community 1.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production (Kg/Hectare)	Foliar Cover (%)
<b>Grass/Grasslike</b>					
1	<b>Mid-Statured Bunchgrasses</b>			729–785	
	rough fescue	FECA4	<i>Festuca campestris</i>	392–673	15–25
	bluebunch wheatgrass	PSSP6	<i>Pseudoroegneria spicata</i>	392–560	15–25
	green needlegrass	NAVI4	<i>Nassella viridula</i>	112–179	3–7
	needle and thread	HECO26	<i>Hesperostipa comata</i>	84–112	3–5
2	<b>Rhizomatous Grasses</b>			67–84	
	western wheatgrass	PASM	<i>Pascopyrum smithii</i>	45–84	3–5
	thickspike wheatgrass	ELLA3	<i>Elymus lanceolatus</i>	0–84	0–5
	plains reedgrass	CAMO	<i>Calamagrostis montanensis</i>	22–45	1–3
3	<b>Shortgrasses</b>			67–84	
	Idaho fescue	FEID	<i>Festuca idahoensis</i>	28–84	3–10
	Sandberg bluegrass	POSE	<i>Poa secunda</i>	22–67	1–8
	prairie Junegrass	KOMA	<i>Koeleria macrantha</i>	22–67	1–5

	threadleaf sedge	CAFI	<i>Carex filifolia</i>	22–67	1–5
	sedge	CAREX	<i>Carex</i>	0–45	0–2
	blue grama	BOGR2	<i>Bouteloua gracilis</i>	0–11	0–1
<b>Forb</b>					
4	<b>Forbs</b>			67–101	
	arrowleaf balsamroot	BASA3	<i>Balsamorhiza sagittata</i>	0–45	0–4
	lupine	LUPIN	<i>Lupinus</i>	22–34	1–5
	American vetch	VIAM	<i>Vicia americana</i>	22–34	1–3
	scarlet globemallow	SPCO	<i>Sphaeralcea coccinea</i>	11–22	1–2
	dotted blazing star	LIPU	<i>Liatris punctata</i>	0–22	0–1
	spiny phlox	PHHO	<i>Phlox hoodii</i>	0–11	0–1
	deathcamas	ZIGAD	<i>Zigadenus</i>	0–6	0–1
<b>Shrub/Vine</b>					
5	<b>Shrubs</b>			67–101	
	common snowberry	SYAL	<i>Symphoricarpos albus</i>	11–112	0–10
	big sagebrush	ARTR2	<i>Artemisia tridentata</i>	67–101	3–12
	currant	RIBES	<i>Ribes</i>	11–67	0–5
	Woods' rose	ROWO	<i>Rosa woodsii</i>	0–56	0–5
	yellow rabbitbrush	CHVI8	<i>Chrysothamnus viscidiflorus</i>	0–45	0–3
6	<b>Subshrubs</b>			11–34	
	winterfat	KRLA2	<i>Krascheninnikovia lanata</i>	11–34	0–2
	prairie sagewort	ARFR4	<i>Artemisia frigida</i>	0–11	0–1
	broom snakeweed	GUSA2	<i>Gutierrezia sarothrae</i>	0–11	0–1
<b>Tree</b>					
7	<b>Coniferous Trees and Tall Shrubs</b>			0–11	
	ponderosa pine	PIPOS	<i>Pinus ponderosa var. scopulorum</i>	0–11	0
	Rocky Mountain juniper	JUSC2	<i>Juniperus scopulorum</i>	0–11	0
	Douglas-fir	PSME	<i>Pseudotsuga menziesii</i>	0–11	0

## Animal community

The Shallow Clay ecological site provides a variety of wildlife habitats for an array of species. Prior to the settlement of this area, large herds of antelope, elk, and bison roamed. Though the bison have been replaced, mostly with domesticated livestock, elk and antelope still frequently utilize this largely intact landscape for winter habitat in areas adjacent to forests.

The relatively high grass component of the Reference Community provides excellent nesting cover for multiple neotropical migratory birds that select for open grasslands, such as the long-billed curlew and McCown's longspur.

Managed livestock grazing is suitable on this site due to the potential to produce an abundance of high-quality forage. This is often a preferred site for grazing by livestock, and animals tend to congregate in these areas. In order to maintain the productivity of the Shallow Clay site, grazing on adjoining sites with less production must be managed carefully to be sure utilization on this site is not excessive. Management objectives should include maintenance or improvement of the native plant community. Careful management of the timing and duration of grazing is important. Shorter grazing periods and adequate deferment during the growing season are recommended for plant maintenance, health, and recovery. According to McLean et al., early-season defoliation of bluebunch wheatgrass can result in high mortality and reduced vigor in plants. Based on previous research, they also believe that regrowth is required before dormancy to reduce bluebunch injury.

Since needle-and-thread normally matures earlier than bluebunch wheatgrass and rough fescue and produces a sharp awn, this species is usually avoided after seed set. Changing the grazing season of use will help utilize needle and thread more efficiently while preventing overuse of bluebunch wheatgrass and rough fescue.

The grazing season has more influence on winterfat than grazing intensity. Late winter or early spring grazing is detrimental. However, early winter grazing may actually be beneficial (Blaisdell 1984).

Continual non-prescribed grazing of this site will be detrimental, will alter the plant composition and production over time, and will result in the transition to the Altered State. Transition to other states will depend on the duration of poorly managed grazing as well as other circumstances such as weather conditions and fire frequency.

The Altered State is subject to further degradation to the Degraded State or Invaded State. Management should focus on grazing management strategies that will prevent further degradation, such as seasonal grazing deferment or winter grazing where feasible. Communities within this state are still stable and healthy under proper management. Forage quantity and/or quality may be substantially decreased from the Reference State.

Grazing is possible in the Invaded State. Invasive species are generally less palatable than native grasses. Forage production is typically greatly reduced in this state. Due to the aggressive nature of invasive species, sites in the Invaded State face an increased risk of further degradation to the Invaded State. Grazing has to be carefully managed to avoid further soil loss and degradation and possible livestock health issues.

Prescriptive grazing can be used to manage invasive species. In some instances, carefully targeted grazing (sometimes in combination with other treatments) can reduce or maintain the species composition of invasive species. In the Degraded State, grazing may be possible but is generally not economically and/or environmentally sustainable.

## **Hydrological functions**

The hydrologic cycle functions best in the Reference State (1) with good infiltration and deep percolation of rainfall; however, the cycle degrades as the vegetation community declines. Rapid rainfall infiltration, high soil organic matter, good soil structure, and good porosity accompany high bunchgrass canopy cover. High ground cover reduces raindrop impact on the soil surface, which keeps erosion and sedimentation transport low. Water leaving the site will have a minimal sediment load, which allows for high water quality in associated streams. High rates of infiltration will allow water to move below the rooting zone during periods of heavy rainfall. The Mid-Staturred Bunchgrass Community (1.1) should have no rills or gullies present, and drainage ways should be vegetated and stable. Water flow patterns, if present, will be barely observable. Plant pedestals are essentially nonexistent. Plant litter remains in place and is not moved by wind or water.

Improper grazing management results in a community shift to the Mixed Bunchgrass Community (1.2). This plant community has a similar canopy cover, but the bare ground will be less than 15 percent covered. Therefore, the hydrologic cycle is functioning at a level similar to the water cycle in the Mid-Staturred Bunchgrass Community (1.1). Infiltration rates are slightly lower and surface runoff is slightly higher than in the Mid-Staturred Bunchgrass Community (1.1).

In the Shortgrass Community (2.2), Degraded State (3), and the Invaded State (4), canopy and ground cover are greatly reduced compared to the Reference State (1), which impedes the hydrologic cycle. Infiltration will decrease and runoff will increase due to reduced ground cover, the presence of shallow-rooted species, rainfall splash, soil capping, reduced organic matter, and poor structure. Sparse ground cover and decreased infiltration can combine to increase the frequency and severity of flooding within a watershed. Soil erosion is accelerated, the quality of surface runoff is poor, and sedimentation increases.

The hydrology of the Conifer Encroached State (5) is highly variable, but studies suggest that an increased tree canopy affects the interception of rainfall as well as the amount of available soil moisture for herbaceous vegetation. This can negatively affect infiltration and increase runoff.

## **Recreational uses**

This site provides recreational opportunities for hiking, horseback riding, big game hunting, and upland bird hunting. Some forbs have flowers that appeal to photographers. This site provides valuable open space.

## Wood products

none

## Other products

none

## Inventory data references

Information presented was derived from the site's Range Site Description, NRCS clipping data, literature, field observations, and personal contacts with range-trained personnel (i.e., used professional opinion of agency specialists, observations of land managers, and outside scientists).

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## Approval

Kirt Walstad, 9/11/2023

## 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)	Grant Petersen
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Date	05/18/2024
Approved by	Kirt Walstad
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

## Indicators

1. **Number and extent of rills:** Rills will not be evident on lesser sloping Reference Communities. Steeper slopes (greater than 30%) may have rills particularly after extreme weather events however they will remain short

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2. **Presence of water flow patterns:** Water flow patterns are not be evident on lesser sloping reference communities however will likely be evident on slopes greater than 30% however they will be short

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3. **Number and height of erosional pedestals or terracettes:** Steep slopes (greater than 30%) may contain both pedestals and terracettes as a result of slow infiltration and higher run-off. Height of either will not exceed ¾" tall.
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4. **Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground):** Bare ground is less than 25%.
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5. **Number of gullies and erosion associated with gullies:** Gullies are not present in the reference condition.
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6. **Extent of wind scoured, blowouts and/or depositional areas:** Wind scoured, or depositional areas are extremely rare in the reference condition.
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7. **Amount of litter movement (describe size and distance expected to travel):** Litter movement of fine herbaceous material is minimal, distance traveled is less than 1 foot in the reference condition.
- 
8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):** The average soil stability rating is 5-6 under plant canopies and 4-6 in plant interspaces. The A horizon is 2-4 inches thick.
- 
9. **Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):** Soil surface structure will be weak, fine to strong medium granular. A Horizon should be 2-4 inches thick with color, when wet, typically ranging in Value of 5 or less and Chroma of 3 or less. Local geology may affect color in which it is important to reference the Official Series Description (OSD) for characteristic range.  
<https://soilseries.sc.egov.usda.gov/osdname.aspx>
- 
10. **Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:** Evenly distributed across the site, deep rooted bunchgrasses improve infiltration while rhizomatous grass protects the surface from runoff forces. Infiltration of the Shallow Clay ecological site is slow but well drained. An even distribution of mid stature bunchgrasses (65-70 percent of site production), cool season rhizomatous grasses (5-10 percent) with a mix of shortgrass (5-10 percent), forbs (1-10 percent) and shrubs (1-10 percent). Trees are rare on this site however may exist as a trace (less than 1 stem per acre)
- 
11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):** A compaction layer is not present in the reference condition.
- 
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: Mid-statured, cool season, perennial bunchgrasses
- Sub-dominant: shortgrass/grasslikes = Rhizomatous grass > forbs ≥ shrubs > subshrubs >> trees/tall shrubs

Other:

Additional:

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13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):** Mortality in herbaceous species is not evident. Species with bunch growth forms may have some natural mortality in centers is 3% or less.
- 

14. **Average percent litter cover (%) and depth ( in):** Total litter cover ranges from 35 to 45%. Most litter is irregularly distributed on the soil surface and is not at a measurable depth.
- 

15. **Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production):** Average annual production is 1250 pounds per acre (lbs/ac) or 1401 kilograms per hectare (kg/ha)  
Low: 1050lb/ac (1177 kg/ha)  
High 1500 (1681 kg/ha)  
Production varies based on effective precipitation and natural variability of soil properties for this ecological site.
- 

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:** Potential invasive (including noxious) species (native and non-native). Invasive species on this ecological site include (but not limited to) annual brome spp., spotted knapweed, yellow toadflax, ventenata, crested wheatgrass, Kentucky bluegrass, smooth brome  
Native species such as rocky mtn Juniper, ponderosa pine, Douglas fir, broom snakeweed, rabbitbrush spp., big sagebrush, blue grama, etc. when their populations are significant enough to affect ecological function, indicate site condition departure.
- 

17. **Perennial plant reproductive capability:** In the reference condition, all plants are vigorous enough for reproduction either by seed or rhizomes in order to balance natural mortality with species recruitment.
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