

Ecological site R108XC507IA Sandy Upland Savanna

Last updated: 7/01/2019
Accessed: 05/18/2024

General information

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

Figure 1. Mapped extent

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

MLRA notes

Major Land Resource Area (MLRA): 108X—Illinois and Iowa Deep Loess and Drift

The Illinois and Iowa Deep Loess and Drift, West-Central Part (MLRA 108C) encompasses the eastern portion of the Southern Iowa Drift Plain and the Lake Calvin basin of the Mississippi Alluvial Plain landforms (Prior 1991). It lies entirely in one state (Iowa), containing approximately 9,805 square miles (Figure 1). The elevation ranges from approximately 1,110 feet above sea level (ASL) on the highest ridges to about 505 feet ASL in the lowest valleys. Local elevation difference is mainly 10 to 20 feet. However, some valley floors can range from 80 to 200 feet, while some upland flats and valley floors only range between 3 and 6 feet. The MLRA is underlain by Pre-Illinoian glacial till, deposited more than 500,000 years ago and since undergone extensive erosion and dissection. In the northern half of the area the till thickness ranges from 150 to 350 feet and grades to less than 150 feet thick in the southern half. The till is covered by a mantle of Peoria Loess on the hillslopes and Holocene alluvium in the drainageways. Paleozoic bedrock, comprised of limestone, shale, and mudstones, lies beneath the glacial material (USDA-NRCS 2006).

The vegetation in the MLRA has undergone drastic changes over time. Spruce forests dominated the landscape 30,000 to 21,500 years ago. As the last glacial maximum peaked 21,500 to 16,000 years ago, they were replaced with open tundras and parklands. The end of the Pleistocene Epoch saw a warming climate that initially prompted the return of spruce forests, but as the warming continued, spruce trees were replaced by deciduous trees (Baker et al. 1990). Not until approximately 9,000 years ago did the vegetation transition to prairies as climatic conditions continued to warm and subsequently dry. Between 4,000 and 3,000 years ago, oak savannas began intermingling within the prairie landscape, while the more wooded and forested areas maintained a foothold in sheltered areas. This prairie-forest transition ecosystem formed the dominant landscapes until the arrival of European settlers (Baker et al. 1992).

LRU notes

Sandy Upland Savannas are located within the green areas on the map (Figure 1). They occur on upland hillslopes and high stream terraces. The soils are Alfisols that are well-drained and deep, formed from loamy eolian deposits.

The historic pre-European settlement vegetation on this ecological site was dominated by oak barrens. Black oak (*Quercus velutina* Lam.) is the dominant tree and little bluestem (*Schizachyrium scoparium* (Michx.) Nash) and roundhead lespedeza (*Lespedeza capitata* Michx.) are the dominant understory species of Sandy Upland Savannas. Northern pin oak (*Quercus ellipsoidalis* E.J. Hill) and white oak (*Quercus alba* L.) may be canopy associates. Other grasses that may occur include big bluestem (*Andropogon gerardii* Vitman) and Pennsylvania sedge (*Carex pensylvanica* Lam.) (NatureServe 2015). Forbs typical of an undisturbed plant community associated

with this ecological site include hoary frostweed (*Helianthemum bicknellii* Fernald), longbranch frostweed (*Helianthemum canadense* (L.) Michx.), and hoary puccoon (*Lithospermum canescens* (Michx.) Lehm.) (Drobney et al. 2001; NatureServe 2015). Shrub cover is sparse to patchy with species such as New Jersey tea (*Ceanothus americanus* L.), leadplant (*Amorpha canescens* Pursh), American hazelnut (*Corylus americana* Walter), and fragrant sumac (*Rhus aromatic* Aiton) (DeLong and Hooper 1996; LANDFIRE 2009; NatureServe 2015). Fire and grazing by large mammals are the primary disturbance factors that maintain this site, while drought and windthrow are secondary disturbances (LANDFIRE 2009).

Classification relationships

USFS Subregions: Central Dissected Till Plains (251C) Section, Central Dissected Till and Loess Plain (251Cc), Mississippi River and Illinois Alluvial Plains (51Cf), Southeast Iowa Rolling Loess Hills (251Ch) Subsections (Cleland et al. 2007)

U.S. EPA Level IV Ecoregion: Rolling Loess Prairies (47f), Upper Mississippi Alluvial Plain (72d) (USEPA 2013)

National Vegetation Classification – Ecological Systems: North-Central Oak Barrens (CES202.727) (NatureServe 2015)

National Vegetation Classification - Plant Associations: *Quercus velutina* – *Quercus ellipsoidalis* – (*Quercus alba*)/*Schizachyrium scoparium* Wooded Grassland (CEGL002492) (Nature Serve 2015)

Biophysical Settings: North-Central Oak Barrens (BpS 4213950) (LANDFIRE 2009)

Natural Resources Conservation Service – Iowa Plant Community Species List: Barrens, Black Oak - Lupine (USDA-NRCS 2007)

Iowa Department of Natural Resources: Sand Savanna (INAI 1984)

Associated sites

R108XC504IA	Loess Upland Savanna Loess parent material including Downs, Downs variant, Greenbush, Hedrick, Ladoga, and New Vienna
R108XC519IA	Wet Upland Drainageway Prairie Alluvial parent material in upland drainageways including Ackmore, Colo, Dockery, Ely, Judson, Radford, Spillville, Vesser, and Zook

Similar sites

R108XC504IA	Loess Upland Savanna Loess Upland Savannas occur higher on the landscape and have loess parent material
R108XC511IA	Till Backslope Savanna Till Backslope Savannas occur in a similar landscape position but have glacial till parent material

Table 1. Dominant plant species

Tree	(1) <i>Quercus velutina</i>
Shrub	Not specified
Herbaceous	(1) <i>Schizachyrium scoparium</i> (2) <i>Lespedeza capitata</i>

Physiographic features

Sandy Upland Savannas occur on upland hillslopes and high stream terraces (Figure 2). They are situated on elevations ranging from approximately 400 to 1499 feet ASL. The site does not experience flooding but rather generates runoff to downslope ecological sites.

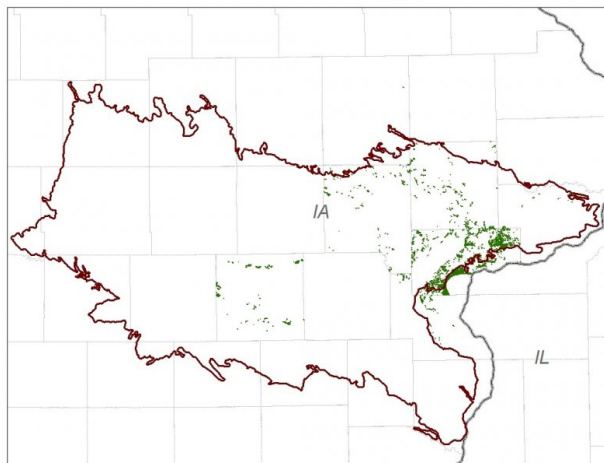


Figure 2. Figure 1. Location of Sandy Upland Savanna ecological site within MLRA 108C.

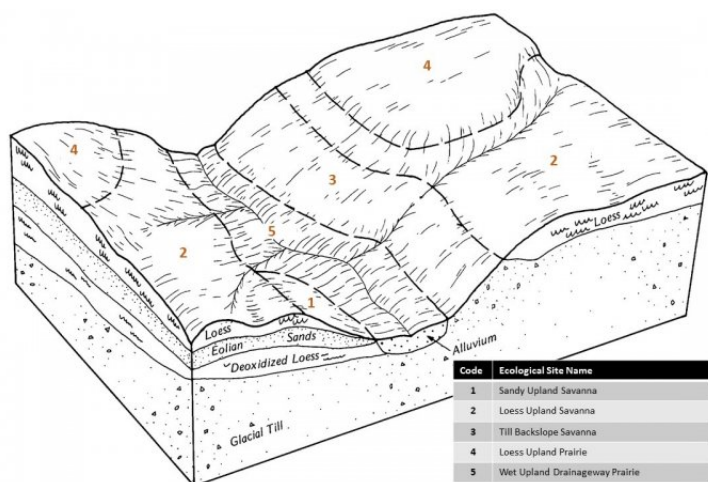


Figure 3. Figure 2. Representative block diagram of Sandy Upland Savanna and associated ecological sites.

Table 2. Representative physiographic features

Slope shape across	(1) Convex
Slope shape up-down	(1) Convex
Landforms	(1) Upland > Hillslope (2) River valley > Terrace
Runoff class	Low to medium
Elevation	122–457 m
Slope	2–14%
Water table depth	203 cm
Aspect	Aspect is not a significant factor

Climatic features

The Illinois and Iowa Deep Loess and Drift, West-Central Part falls into the hot humid continental climate (Dfa) Köppen-Geiger climate classification (Peel et al. 2007). In winter, dry, cold air masses periodically shift south from Canada. As these air masses collide with humid air, snowfall and rainfall result. In summer, moist, warm air masses from the Gulf of Mexico migrate north, producing significant frontal or convective rains. Occasionally, hot, dry winds originating from the Desert Southwest will stagnate over the region, creating extended droughty periods in the summer from unusually high temperatures. Air masses from the Pacific Ocean can also spread into the region and dominate producing mild, dry weather in the autumn known as Indian Summers (NCDC 2006).

The soil temperature regime of MLRA 108C is classified as mesic, where the mean annual soil temperature is

between 46 and 59°F (USDA-NRCS 2006). Temperature and precipitation occur along a north-south gradient, where temperature and precipitation increase the further south one travels. The average freeze-free period of this ecological site is about 192 days, while the frost-free period is about 162 days (Table 2). The majority of the precipitation occurs as rainfall in the form of convective thunderstorms during the growing season. Average annual precipitation is approximately 39 inches, which includes rainfall plus the water equivalent from snowfall (Table 3). The average annual low and high temperatures are 40 and 61°F, respectively.

Climate data and analyses are derived from 30-year averages gathered from three National Oceanic and Atmospheric Administration (NOAA) weather stations contained within the range of this ecological site (Table 4).

Table 3. Representative climatic features

Frost-free period (characteristic range)	143-163 days
Freeze-free period (characteristic range)	171-183 days
Precipitation total (characteristic range)	940-965 mm
Frost-free period (actual range)	140-170 days
Freeze-free period (actual range)	167-185 days
Precipitation total (actual range)	940-991 mm
Frost-free period (average)	153 days
Freeze-free period (average)	177 days
Precipitation total (average)	965 mm

Climate stations used

- (1) IOWA CITY [USC00134101], Iowa City, IA
- (2) COLUMBUS JUNCT 1 N [USC00131731], Columbus Junction, IA
- (3) MUSCATINE 2N [USC00135844], Muscatine, IA

Influencing water features

Sandy Upland Savannas are not influenced by wetland or riparian water features. Precipitation is the main source of water for this ecological site. Infiltration is slow to high (Hydrologic Groups A, B, and C), and surface runoff is low to medium. Precipitation infiltrates the soil surface and percolates downward through the horizons unimpeded by any restrictive layer. The underlying Mississippian bedrock aquifer has few creviced openings throughout the MLRA, restricting recharge from this ecological site. However, there are numerous surficial aquifers that are shallow and allow recharge via percolation (Prior et al. 2003). Surface runoff contributes some water to downslope ecological sites (Figure 5).

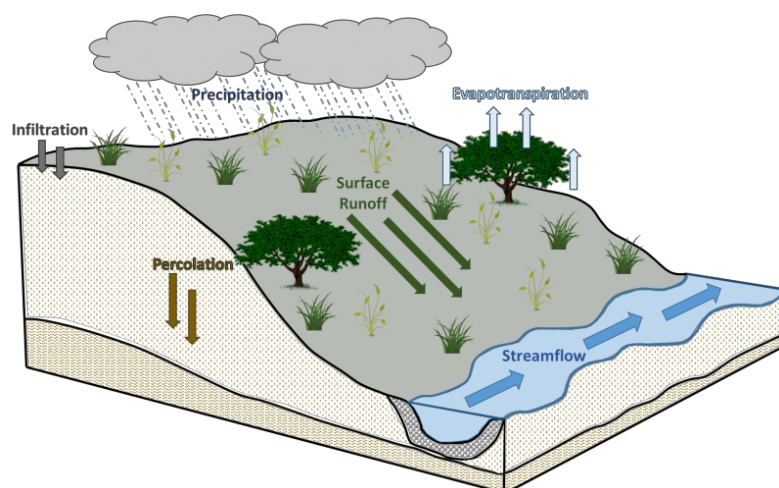


Figure 8. Figure 5. Hydrologic cycling in Sandy Upland Savanna ecological site.

Soil features

Soils of Sandy Upland Savannas are in the Alfisols order, further classified as Mollic Hapludalfs with slow to fast infiltration and low to medium runoff potential. The soil series associated with this site includes Billett, Orwood, and Whittier (Figure 6). The parent material is loamy eolian deposits, and the soils are well-drained and deep. Soil pH classes are strongly acid to neutral. No rooting restrictions are noted for the soils of this ecological site (Table 5).

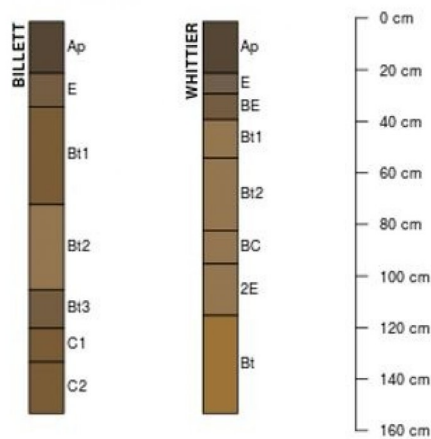


Figure 9. Figure 6. Profile sketches of soil series associated with Sandy Upland Savanna.

Table 4. Representative soil features

Parent material	(1) Eolian sands
Family particle size	(1) Fine-silty over sandy or sandy-skeletal (2) Fine-loamy (3) Coarse-loamy
Drainage class	Well drained
Permeability class	Slow to moderate
Soil depth	203 cm

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 MLRA lies within the transition zone between the eastern deciduous forests and the tallgrass prairies. The heterogeneous topography of the area results in variable microclimates and fuel matrices that in turn are able to support prairies, savannas, woodlands, and forests. Sandy Upland Savannas form an aspect of this vegetative continuum. This ecological site occurs on upland hillslopes and high stream terraces on well-drained soils. Species characteristic of this ecological site consist of herbaceous vegetation with an open canopy of deciduous trees.

Fire and grazing are critical disturbance factors that maintain Sandy Upland Savannas. Fire typically consisted of low-intensity surface fires occurring annually or near annually (LANDFIRE 2009). Ignition sources included summertime lightning strikes from convective storms and bimodal, human ignitions during the spring and fall seasons. Native Americans regularly set fires to improve sight lines for hunting, driving large game, improving grazing and browsing habitat, agricultural clearing, and enhancing vital ethnobotanical plants (Barrett 1980). Bison (*Bos bison*) and prairie elk (*Cervus elaphus*) were the main herbivores in central tallgrass prairies. Herbivory occurred via mob grazing with large herds of animals rapidly moving across the prairie as they grazed. These continuous disturbances provided critical conditions for perpetuating the native savanna ecosystem (LANDFIRE 2009).

Drought and windthrow have also played a role in shaping this ecological site. The periodic episodes of reduced soil moisture in conjunction with the well-drained soils have favored the proliferation of plant species tolerant of such conditions. Drought can also slow the growth of plants and result in dieback of certain species. Damage to trees from storms can vary from minor, patchy effects of individual trees to stand effects that temporarily affect community structure and species richness and diversity (Irland 2000; Peterson 2000). When coupled with fire and herbivory, periods of drought can greatly delay the establishment of woody vegetation (Pyne et al. 1996).

Today, Sandy Upland Savannas are considered to be extirpated from the MLRA, having been converted for agricultural production (NatureServe 2015). Remnants that do exist have had fire suppressed long enough to allow the site to convert to a closed canopy forest. A return to the historic plant community may not be possible following extensive land modification, but long-term conservation agriculture or savanna reconstruction efforts can help to restore some biotic diversity and ecological function. The state-and-transition model that follows provides a detailed description of each state, community phase, pathway, and transition. This model is based on available experimental research, field observations, literature reviews, professional consensus, and interpretations.

STATE 1 – REFERENCE STATE

The reference plant community is categorized as a sand savanna community, dominated by herbaceous vegetation with sparse trees. The two community phases within the reference state are dependent on fire and large mammal herbivory. The amount and duration of grazing alters species composition, cover, and extent, while regular fire intervals keep woody species from dominating. Drought and windthrow have more localized impacts in the reference phases, but do contribute to overall species composition, diversity, cover, and productivity.

Community Phase 1.1 Black Oak/Little Bluestem – Roundhead Lespedeza – Sites in this reference community phase are dominated by prairie grasses and forbs with scattered trees. Black oak is the dominant tree species, but white oak and northern pin oak may occur (NatureServe 2015). Vegetative cover is continuous, and trees comprise no more than 20 percent canopy cover (LANDFIRE 2009). Little bluestem, Pennsylvania sedge, and big bluestem are the dominant grasses. Characteristic forbs include roundhead lespedeza, field pussytoes (*Antennaria neglecta* Greene), woman's tobacco (*Antennaria plantaginifolia* (L.) Richardson), flowering spurge (*Euphorbia corollata* L.), and fringleaf wild petunia (*Ruellia humilis* Nutt.) (DeLong and Hooper 1996; NatureServe 2015). Frequent surface fires occurring approximately every five years in conjunction with native grazing will maintain this phase, but an extended fire return interval would allow more woody species development shifting the community to phase 1.2 (LANDFIRE 2009).

Pathway 1.1A – Natural succession following an extended fire return interval.

Community Phase 1.2 Black Oak/American Hazelnut – New Jersey Tea/Little Bluestem – Roundhead Lespedeza – This reference community phase represents natural succession as a result of an extended fire return interval, such as from drought. The lack of fire allows woody species, such as American hazelnut, New Jersey tea, and fragrant sumac to develop as clumps in the shrub layer. Trees mature as well and canopy closure ranges from 21 to 60 percent (LANDFIRE 2009). The canopy is still considered open, but forbs may increase their dominance as the shrub and tree cover increases (NatureServe 2015).

Pathway 1.2A – Natural succession following a large replacement fire.

Transition 1A – Long-term fire suppression transitions the site to the fire-suppressed state (2).

Transition 1B – Cultural treatments to enhance forage quality and yield transitions the site to the forage state (3).

Transition 1C – Tillage, seeding of agricultural crops, and non-selective herbicide transition the site to the cropland state (4).

STATE 2 – FIRE-SUPPRESSED STATE

Long-term fire suppression can transition the reference plant community from an open savanna to a closed canopy forest. As the natural fire regime is removed from the landscape, encroachment and dominance by shade-tolerant,

fire-intolerant species ensues (Asbjornsen et al. 2005). This results in a positive feedback loop of mesophication whereby plant community succession continuously creates cool, damp shaded conditions that perpetuate a closed canopy ecosystem (Nowacki and Abrams 2008). Succession to this forested state can occur in as little as 25 years from the last fire (LANDFIRE 2009).

Community Phase 2.1 Black Oak – White Oak/American Hazelnut/Pennsylvania Sedge – This community phase represents the early stages of long-term fire suppression. In the absence of fire, trees and shrubs can become dominant, shifting the community structure from an open to a closed woodland with high stem density. Black oak is the dominant tree, but white oak and northern pin oak mature as well. Trees are very large (>33 inches DBH) and cover ranges from 61 to 80 percent (LANDFIRE 2009). American hazelnut can remain in the shrub layer during this closed woodland phase (Colandonato 1993). Under the heavier shade, the herbaceous sun-loving prairie species are replaced with species tolerant of moderate shading.

Pathway 2.1A – Continued fire suppression.

Community Phase 2.2 Black Oak – White Oak/Pennsylvania Sedge – American Hogpeanut – Sites falling into this community phase have a well-established tree canopy that ranges from 81 to 100 percent (LANDFIRE 2009). Tree densities may reach as high as several hundred trees per hectare, and tree size class is reduced under increasing competition for resources. Under these closed-canopy stands, the shrub layer is nearly excluded while Pennsylvania sedge may form dense sods. Forb diversity is limited and may include American hogpeanut (*Amphicarpaea bracteata* (L.) Fernald), spotted geranium (*Geranium maculatum* L.), and feathery false lily of the valley (*Maianthemum racemosum* (L.) Link) (NatureServe 2015).

Pathway 2.2A – Severe disturbance event such as a replacement fire, severe drought, or windstorm.

Transition 2A – Cultural treatments to enhance forage quality and yield transitions the site to the forage state (3).

Transition 2B – Tillage, seeding of agricultural crops, and non-selective herbicide transition this site to the cropland state (4).

Restoration 2A – Site preparation, invasive species control, and seeding native species transition this site to the reconstructed sand savanna state (5).

STATE 3 – FORAGE STATE

The forage state occurs when the reference state is converted to a farming system that emphasizes domestic livestock production known as grassland agriculture. Fire suppression, periodic cultural treatments (e.g., clipping, drainage, soil amendment applications, planting new species and/or cultivars, mechanical harvesting) and grazing by domesticated livestock transition and maintain this state (USDA-NRCS 2003). Early settlers seeded non-native species, such as smooth brome (*Bromus inermis* Leyss.) and Kentucky bluegrass (*Poa pratensis* L.), to help extend the grazing season (Smith 1998). Over time, as lands were continuously harvested or grazed by herds of cattle, the non-native species were able to spread and expand across the landscape, reducing the native species diversity and ecological function.

Community Phase 3.1 Hayfield – Sites in this community phase consist of forage plants that are planted and mechanically harvested. Mechanical harvesting removes much of the aboveground biomass and nutrients that feed the soil microorganisms (Franzluebbers et al. 2000; USDA-NRCS 2003). As a result, soil biology is reduced leading to decreases in nutrient uptake by plants, soil organic matter, and soil aggregation. Frequent biomass removal can also reduce the site's carbon sequestration capacity (Skinner 2008).

Pathway 3.1A – Mechanical harvesting is replaced with domestic livestock utilizing continuous grazing.

Pathway 3.1B – Mechanical harvesting is replaced with domestic livestock utilizing rotational grazing.

Community Phase 3.2 Continuous Pastured Grazing System – This community phase is characterized by continuous grazing where domestic livestock graze a pasture for the entire season. Depending on stocking density, this can result in lower forage quality and productivity, weed invasions, and uneven pasture use. Continuous

grazing can also increase the amount of bare ground and erosion and reduce soil organic matter, cation exchange capacity, water-holding capacity, and nutrient availability and retention (Bharati et al. 2002; Leake et al. 2004; Teague et al. 2011). Smooth brome, Kentucky bluegrass, and white clover (*Trifolium repens* L.) are common pasture species used in this phase. Their tolerance to continuous grazing has allowed these species to dominate, sometimes completely excluding the native vegetation.

Pathway 3.2A – Domestic livestock are removed, and mechanical harvesting is implemented.

Pathway 3.2B – Rotational grazing replaces continuous grazing.

Community Phase 3.3 Rest-Rotation Pastured Grazing System – This community phase is characterized by rotational grazing where the pasture has been subdivided into several smaller paddocks. Through the development of a grazing plan, livestock utilize one or a few paddocks, while the remaining area is rested allowing plants to restore vigor and energy reserves, deepen root systems, develop seeds, as well as allow seedling establishment (Undersander et al. 2002; USDA-NRCS 2003). Rest-rotation pastured grazing systems include deferred rotation, rest rotation, high intensity – low frequency, and short duration methods. Vegetation is generally more diverse and can include orchardgrass (*Dactylis glomerata* L.), timothy (*Phleum pratense* L.), red clover (*Trifolium pratense* L.), and alfalfa (*Medicago sativa* L.). The addition of native prairie species can further bolster plant diversity and, in turn, soil function. This community phase promotes numerous ecosystem benefits including increasing biodiversity, preventing soil erosion, maintaining and enhancing soil quality, sequestering atmospheric carbon, and improving water yield and quality (USDA-NRCS 2003).

Pathway 3.3A – Continuous grazing replaces rotational grazing.

Pathway 3.3B – Domestic livestock are removed, and mechanical harvesting is implemented.

Transition 3A – Land abandonment transitions the site to the fire-suppressed state (2).

Transition 3B – Tillage, seeding of agricultural crops, and non-selective herbicide transition this site to the cropland state (4).

Restoration 3A – Site preparation, invasive species control, and seeding native species transition this site to the reconstructed sand savanna state (5).

STATE 4 – CROPLAND STATE

The low topographic relief across the MLRA has resulted in nearly the entire area being converted to agriculture (Eilers and Roosa 1994). The continuous use of tillage, row-crop planting, and chemicals (i.e., herbicides, fertilizers, etc.) has effectively eliminated the reference community and many of its natural ecological functions in favor of crop production. Corn and soybeans are the dominant crops for the site, and oats (*Avena* L.) and alfalfa (*Medicago sativa* L.) may be rotated periodically. These areas are likely to remain in crop production for the foreseeable future.

Community Phase 4.1 Conventional Tillage Field – Sites in this community phase typically consist of monoculture row-cropping maintained by conventional tillage practices. They are cropped in either continuous corn or corn-soybean rotations. The frequent use of deep tillage, low crop diversity, and bare soil conditions during the non-growing season negatively impacts soil health. Under these practices, soil aggregation is reduced or destroyed, soil organic matter is reduced, erosion and runoff are increased, and infiltration is decreased, which can ultimately lead to undesirable changes in the hydrology of the watershed (Tomer et al. 2005).

Pathway 4.1A – Tillage operations are greatly reduced, crop rotation occurs on a regular interval, and crop residue remains on the soil surface.

Pathway 4.1B – Tillage operations are greatly reduced or eliminated, crop rotation occurs on a regular interval, crop residue remains on the soil surface, and cover crops are planted following crop harvest.

Community Phase 4.2 Conservation Tillage Field – This community phase is characterized by rotational crop production that utilizes various conservation tillage methods to promote soil health and reduce erosion.

Conservation tillage methods include strip-till, ridge-till, vertical-till, or no-till planting systems. Strip-till keeps seedbed preparation to narrow bands less than one-third the width of the row where crop residue and soil consolidation are left undisturbed in-between seedbed areas. Strip-till planting may be completed in the fall and nutrient application either occurs simultaneously or at the time of planting. Ridge-till uses specialized equipment to create ridges in the seedbed and vegetative residue is left on the surface in between the ridges. Weeds are controlled with herbicides and/or cultivation, seedbed ridges are rebuilt during cultivation, and soils are left undisturbed from harvest to planting. Vertical-till systems employ machinery that lightly tills the soil and cuts up crop residue, mixing some of the residue into the top few inches of the soil while leaving a large portion on the surface. No-till management is the most conservative, disturbing soils only at the time of planting and fertilizer application. Compared to conventional tillage systems, conservation tillage methods can improve soil ecosystem function by reducing soil erosion, increasing organic matter and water availability, improving water quality, and reducing soil compaction.

Pathway 4.2A – Intensive tillage is utilized, and monoculture row-cropping is established.

Pathway 4.2B – Cover crops are implemented to minimize soil erosion.

Community Phase 4.3 Conservation Tillage with Cover Crop Field – This community phase applies conservation tillage methods as described above as well as adds cover crop practices. Cover crops typically include nitrogen-fixing species (e.g., legumes), small grains (e.g., rye, wheat, oats), or forage covers (e.g., turnips, radishes, rapeseed). The addition of cover crops not only adds plant diversity but also promotes soil health by reducing soil erosion, limiting nitrogen leaching, suppressing weeds, increasing soil organic matter, and improving the overall soil ecosystem. In the case of small grain cover crops, surface cover and water infiltration are increased, while forage covers can be used to graze livestock or support local wildlife. Of the three community phases for this state, this phase promotes the greatest soil sustainability and improves ecological functioning within a cropland system.

Pathway 4.3A – Cover crop practices are abandoned.

Pathway 4.3B – Intensive tillage is utilized, cover crops practices are abandoned, monoculture row-cropping is established, and crop rotation is reduced or eliminated.

Transition 4A – Land abandonment transitions the site to the fire-suppressed state (2).

Transition 4B – Cultural treatments to enhance forage quality and yield transitions the site to the forage state (3).

Restoration 4A – Site preparation, invasive species control, and seeding native species transition this site to the reconstructed sand savanna state (5).

STATE 5 – RECONSTRUCTED SAND SAVANNA STATE

Savanna reconstructions have become an important tool for repairing natural ecological functions and providing habitat protection for numerous grassland dependent species. Because the historic plant and soil biota communities of the tallgrass habitats were highly diverse with complex interrelationships, historic savanna replication cannot be guaranteed on landscapes that have been so extensively manipulated for extended timeframes (Kardol and Wardle 2010; Fierer et al. 2013). Therefore, ecological restoration should aim to aid the recovery of degraded, damaged, or destroyed ecosystems. A successful restoration will have the ability to structurally and functionally sustain itself, demonstrate resilience to the natural ranges of stress and disturbance, and create and maintain positive biotic and abiotic interactions (SER 2002). The reconstructed savanna state is the result of a long-term commitment involving a multi-step, adaptive management process. Oak plantings or selective thinning of non-oak species will be required to reproduce the overstory canopy (Asbjornsen et al. 2005). Diverse, species-rich seed mixes may be important to utilize as they allow the site to undergo successional stages that exhibit changing composition and dominance over time (Smith et al. 2010). On-going management via prescribed fire and/or light grazing will help the site progress from an early successional community dominated by annuals and some weeds to a later seral stage composed of native perennial grasses, forbs, shrubs, and eventually mature oaks. Establishing a prescribed fire regime that mimics natural disturbance patterns can increase native species cover and diversity while reducing cover of non-native forbs and grasses. Light grazing alone can help promote species richness, while grazing accompanied with fire can control the encroachment of undesirable woody vegetation (Brudvig et al. 2007).

Community Phase 5.1 Early Successional Reconstructed Oak Savanna – This community phase represents early community assembly and is highly dependent on the timing and priority of planting and/or tree thinning operations and the herbaceous seed mix utilized. If oak plantings are needed, acorns should be planted shortly after harvest as acorns germinate shortly after seedfall and require no cold stratification. Browse protection may need to be installed to protect newly established seedlings from animal predation. If selective tree removal is needed, canopy reduction should encompass between 16 to 45 percent of the undesirable species in a single year (Asbjornsen et al. 2005). The seed mix should look to include a diverse mix of native cool-season and warm-season annual and perennial grasses and forbs typical of the reference state. Native, cool-season annuals can help to provide litter that promotes cool, moist soil conditions to the benefit of the other species in the seed mix. The first season following site preparation and seeding will typically result in annuals and other volunteer species forming a majority of the vegetative cover. Control of non-native species, particularly perennial species, is crucial at this point to ensure they do not establish before the native vegetation (Martin and Wilsey 2012). After the first season, native warm-season grasses should begin to become more prominent on the landscape and over time close the canopy.

Pathway 4.1A – Selective herbicides are used to control non-native species, and prescribed fire and/or light grazing help to increase the native species diversity and control non-oak woody vegetation.

Community Phase 5.2 Late Successional Reconstructed Oak Savanna – Appropriately timed disturbance regimes (e.g., prescribed fire) applied to the early successional community phase can help increase the beta diversity, pushing the site into a late successional community phase over time. While oak savanna communities are dominated by grasses, these species can suppress forb establishment and reduce overall diversity and ecological functioning (Martin and Wilsey 2006; Williams et al. 2007). Reducing accumulated plant litter from such tallgrasses as big bluestem and Indiangrass allows more light and nutrients to become available for forb recruitment, allowing for greater ecosystem complexity (Wilsey 2008).

Pathway 5.2B – Reconstruction experiences a decrease in native species diversity from drought or improper timing of management actions (e.g., reduced fire frequency, use of non-selective herbicides).

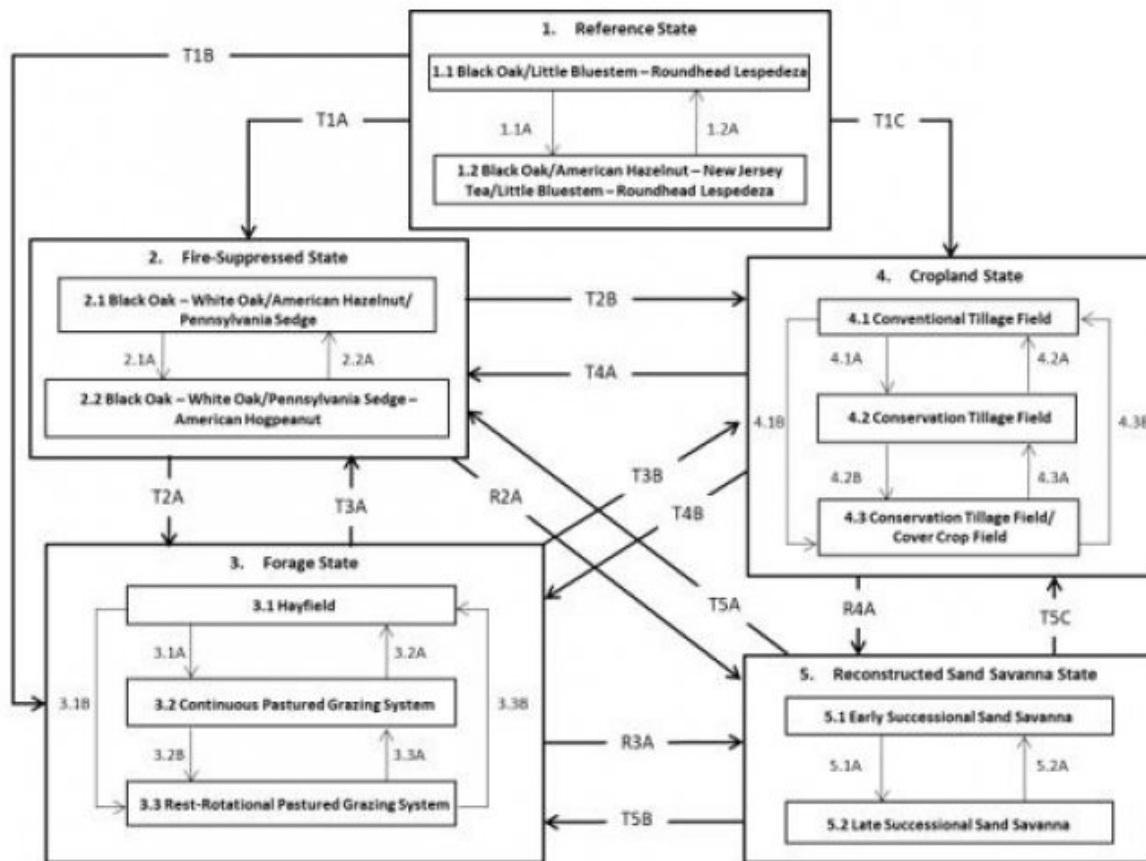
Transition 5A – Fire suppression and removal of active management transitions this site to the fire-suppressed state (2).

Transition 5B – Cultural treatments to enhance forage quality and yield transition the site to the forage state (3).

Transition 5C – Tillage, seeding of agricultural crops, and non-selective herbicide transition this site to the cropland state (4).

State and transition model

R108CY507IA SANDY UPLAND SAVANNA



Code	Process
1.1A	Reduced fire return interval
1.2A	Increased fire return interval
T1A, T3A, T4A, T5A	Long-term fire suppression and/or land abandonment
2.1A	Continued fire suppression
2.2A	Severe disturbance event such as fire, drought, or windstorm
T1B, T2A, T4B, T5B	Cultural treatments are implemented to increase forage quality and yield
3.1A	Mechanical harvesting is replaced with domestic livestock and continuous grazing
3.1B	Mechanical harvesting is replaced with domestic livestock and rest-rotational grazing
3.2A, 3.3B	Domestic livestock grazing is replaced by mechanical harvesting
3.2B	Implementation of rest-rotational grazing
3.3A	Implementation of continuous grazing
T1C, T2B, T3B, T5C	Agricultural conversion via tillage, seeding, and non-selective herbicide
4.1A	Less tillage, residue management
4.1B	Less tillage, residue management, and implementation of cover cropping
4.2B	Implementation of cover cropping
4.2A, 4.3B	Intensive tillage, remove residue, and reinitiate monoculture row cropping
4.3A	Remove cover cropping
R2A, R3A, R4A	Site preparation, non-native species control, and native seeding
5.1A	Invasive species control and implementation of disturbance regimes
5.2A	Drought or improper timing/use of management actions

Inventory data references

No field plots were available for this site. A review of the scientific literature and professional experience were used to approximate the plant communities for this provisional ecological site. Information for the state-and-transition model was obtained from the same sources. All community phases are considered provisional based on these plots and the sources identified in ecological site description.

Other references

- Asbjornsen, H., L.A. Brudvig, C.M. Mabry, C.W. Evans, and H.M. Karnitz. 2005. Defining reference information for restoring ecologically rare tallgrass oak savannas in the midwestern United States. *Journal of Forestry* 103: 345-350.
- Baker, R.G., C.A. Chumbley, P.M. Witinok, and H.K. Kim. 1990. Holocene vegetational changes in eastern Iowa. *Journal of the Iowa Academy of Science* 97: 167-177.
- Baker, R.G., L.J. Maher, C.A. Chumbley, and K.L. Van Zant. 1992. Patterns of Holocene environmental changes in the midwestern United States. *Quaternary Research* 37: 379-389.
- Barrett, S.W. 1980. Indians and fire. *Western Wildlands Spring*: 17-20.
- Bharati, L., K.-H. Lee, T.M. Isenhardt, and R.C. Schultz. 2002. Soil-water infiltration under crops, pasture, and established riparian buffer in Midwestern USA. *Agroforestry Systems* 56: 249-257.
- Brudvig, L.A., C.M. Mabry, J.R. Miller, and T.A. Walker. 2007. Evaluation of central North American prairie management based on species diversity, life form, and individual species metrics. *Conservation Biology* 21: 864-874.
- Cleland, D.T., J.A. Freeouf, J.E. Keys, G.J. Nowacki, C. Carpenter, and W.H. McNab. 2007. Ecological Subregions: Sections and Subsections of the Coterminous United States. USDA Forest Service, General Technical Report WO-76. Washington, DC. 92 pps.
- Colandonato, M. 1993. *Corylus americana*. In: Fire Sciences Information System [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available at <https://www.crs-feis.org/feis/>. (Accessed 20 March 2018).
- Delong, K.T. and C. Hooper. 1996. A potential understory flora for oak savanna in Iowa. *Journal of the Iowa Academy of Sciences* 103: 9-28.
- Drobney, P.D., G.S. Wilhelm, D. Horton, M. Leoschke, D. Lewis, J. Pearson, D. Roosa, and D. Smith. 2001. Floristic Quality Assessment for the State of Iowa. Neal Smith National Wildlife Refuge and Ada Hayden Herbarium, Iowa State University, Ames, IA. 123 pps.
- Eilers, L. and D. Roosa. 1994. *The Vascular Plants of Iowa: An Annotated Checklist and Natural History*. University of Iowa Press, Iowa City, IA. 319 pps.
- Fierer, N., J. Ladau, J.C. Clemente, J.W. Leff, S.M. Owens, K.S. Pollard, R. Knight, J.A. Gilbert, and R.L. McCulley. 2013. Reconstructing the microbial diversity and function of pre-agricultural tallgrass prairie soils in the United States. *Science* 342: 621-624.
- Franzluebbers, A.J., J.A. Stuedemann, H.H. Schomberg, and S.R. Wilkinson. 2000. Soil organic C and N pools under long-term pasture management in the Southern Piedmont USA. *Soil Biology and Biochemistry* 32:469-478.
- Iowa Natural Areas Inventory [INAI]. 1984. *An Inventory of Significant Natural Areas in Iowa: Two Year Progress Report of the Iowa Natural Areas Inventory*. Iowa Natural Areas Inventory, Iowa Department of Natural Resources, Des Moines, IA.
- Ireland, L.C. 2000. Ice storms and forest impacts. *The Science of the Total Environment* 262:231-242.
- Karol, P. and D.A. Wardle. 2010. How understanding aboveground-belowground linkages can assist restoration ecology. *Trends in Ecology and Evolution* 25: 670-679.
- LANDFIRE. 2009. Biophysical Setting 4213940 North-Central Interior Oak Savanna. In: LANDFIRE National Vegetation Dynamics Models. USDA Forest Service and US Department of Interior. Washington, DC.

- Leake, J., D. Johnson, D. Donnelly, G. Muckle, L. Boddy, and D. Read. 2004. Networks of power and influence: the role of mycorrhizal mycelium in controlling plant communities and agroecosystem functioning. *Canadian Journal of Botany* 82: 1016-1045.
- Martin, L.M. and B.J. Wilsey. 2006. Assessing grassland restoration success: relative roles of seed additions and native ungulate activities. *Journal of Applied Ecology* 43: 1098-1110.
- Martin, L.M. and B.J. Wilsey. 2012. Assembly history alters alpha and beta diversity, exotic-native proportions and functioning of restored prairie plant communities. *Journal of Applied Ecology* 49: 1436-1445.
- National Climate Data Center [NCDC]. 2006. Climate of Iowa. Central Region Headquarters, Climate Services Branch, National Climatic Data Center, Asheville, NC.
- NatureServe. 2015. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1 NatureServe, Arlington, VA. Available at <http://explorer.natureserve.org>. (Accessed 13 February 2017).
- Nowacki, G.J. and M.D. Abrams. 2008. The demise of fire and “mesophication” of forests in the eastern United States. *BioScience* 58: 123-138.
- Peel, M.C., B.L. Finlayson, and T.A. McMahon. 2007. Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences* 11: 1633-1644.
- Peterson, C.J. 2000. Catastrophic wind damage to North American forests and the potential impact of climate change. *The Science of the Total Environment* 262: 287-311.
- Prior, J.C. 1991. Landforms of Iowa. University of Iowa Press for the Iowa Department of Natural Resources, Iowa City, IA. 153 pps.
- Prior, J.C., J.L. Boekhoff, M.R. Howes, R.D. Libra, and P.E. VanDorpe. 2003. Iowa's Groundwater Basics: A Geological Guide to the Occurrence, Use, & Vulnerability of Iowa's Aquifers. Iowa Department of Natural Resources, Iowa Geological Survey Educational Series 6. 92 pps.
- Pyne, S.J., P.L. Andrews, and R.D. Laven. 1996. Introduction to Wildland Fire, Second Edition. John Wiley and Sons, Inc. New York, New York. 808 pps.
- Skinner, R.H. 2008. High biomass removal limits carbon sequestration potential of mature temperate pastures. *Journal for Environmental Quality* 37: 1319-1326.
- Smith, D.D. 1998. Iowa prairie: original extent and loss, preservation, and recovery attempts. *The Journal of the Iowa Academy of Sciences* 105: 94-108.
- Smith, D.D., D. Williams, G. Houseal, and K. Henderson. 2010. The Tallgrass Prairie Center Guide to Prairie Restoration in the Upper Midwest. University of Iowa Press, Iowa City, IA. 338 pps.
- Society for Ecological Restoration [SER] Science & Policy Working Group. 2002. The SER Primer on Ecological Restoration. Available at: <http://www.ser.org/>. (Accessed 28 February 2017).
- Teague, W.R., S.L. Dowhower, S.A. Baker, N. Haile, P.B. DeLaune, and D.M. Conover. 2011. Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie. *Agriculture, Ecosystems and Environment* 141: 310-322.
- Tomer, M.D., D.W. Meek, and L.A. Kramer. 2005. Agricultural practices influence flow regimes of headwater streams in western Iowa. *Journal of Environmental Quality* 34:1547-1558.
- Undersander, D., B. Albert, D. Cosgrove, D. Johnson, and P. Peterson. 2002. Pastures for Profit: A Guide to Rotational Grazing (A3529). University of Wisconsin-Extension and University of Minnesota Extension Service. 43 pps.

United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS). 2003. National Range and Pasture Handbook, Revision 1. Grazing Lands Technology Institute. 214 pps.

United States Department of Agriculture – Natural Resource Conservation Service (USDA-NRCS). 2006. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. 682 pps.

United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS). 2007. Iowa NRCS Plant Community Species Lists. Des Moines, IA. Available at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ia/technical/ecoscience/bio/?cid=nrcs142p2_008160. (Accessed 19 January 2018).

U.S. Environmental Protection Agency [EPA]. 2013. Level III and Level IV Ecoregions of the Continental United States. Corvallis, OR, U.S. EPA, National Health and Environmental Effects Research Laboratory, map scale 1: 3,000,000. Available at <http://www.epa.gov/eco-research/level-iii-andiv-ecoregions-continental-united-states>. (Accessed 1 March 2017).

Williams, D.A., L.L. Jackson, and D.D Smith. 2007. Effects of frequent mowing on survival and persistence of forbs seeded into a species-poor grassland. *Restoration Ecology* 15: 24-33.

Wilsey, B.J. 2008. Productivity and subordinate species response to dominant grass species and seed source during restoration. *Restoration Ecology* 18: 628-637.

Contributors

Lisa Kluesner
Ryan Dermody

Approval

lisa kluesner, 7/01/2019

Acknowledgments

This project could not have been completed without the dedication and commitment from a variety of partners and staff (Table 6). Team members supported the project by serving on the technical team, assisting with the development of state and community phases of the state-and-transition model, providing peer review and technical editing, and conducting quality control and quality assurance reviews.

Organization Name Title Location

Drake University:

Dr. Tom Rosburg Professor of Ecology and Botany Des Moines, IA

Iowa Department of Natural Resources:

Kevin Andersen Private Lands Biologist Fairfield, IA

John Pearson Ecologist Des Moines, IA

LANDFIRE (The Nature Conservancy):

Randy Swaty Ecologist Evanston, IL

Natural Resources Conservation Service:

Rick Bednarek Iowa State Soil Scientist Des Moines, IA

Leland Camp Soil Scientist Waverly, IA

Stacey Clark Regional Ecological Site Specialist St. Paul, MN

Ryan Dermody Soil Survey Leader Waverly, IA

Tonie Endres Senior Regional Soil Scientist Indianapolis, IN

John Hammerly Soil Data Quality Specialist Indianapolis, IN

Lisa Kluesner Ecological Site Specialist Waverly, IA

Sean Kluesner Earth Team Volunteer Waverly, IA
Jeff Matthias State Grassland Specialist Des Moines, IA
Kevin Norwood Soil Survey Regional Director Indianapolis, IN
Doug Oelmann Soil Scientist Des Moines, IA
James Phillips GIS Specialist Des Moines, IA
Jason Steele Area Resource Soil Scientist Fairfield, IA
Doug Wallace Ecologist ACES Program Columbia, MO

Rangeland health reference sheet

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

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

Indicators

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

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

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

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

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

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

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

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

-
9. **Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):**
-
10. **Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:**
-
11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):**
-
12. **Functional/Structural Groups (list in order of descending dominance by above-ground annual-production or live foliar cover using symbols: >>, >, = to indicate much greater than, greater than, and equal to):**
- Dominant:
- Sub-dominant:
- Other:
- Additional:
-
13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):**
-
14. **Average percent litter cover (%) and depth (in):**
-
15. **Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production):**
-
16. **Potential invasive (including noxious) species (native and non-native). List species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicators, we are describing what is NOT expected in the reference state for the ecological site:**
-
17. **Perennial plant reproductive capability:**
-