

## Ecological site R108XC516IA Wet Loess Upland Flat Prairie

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### General information

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

#### Figure 1. Mapped extent

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

### MLRA notes

Major Land Resource Area (MLRA): 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).

### 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: Central Tallgrass Prairie (CES205.683) (NatureServe 2015)

National Vegetation Classification - Plant Associations: *Andropogon gerardii* – *Panicum virgatum* – *Helianthus grosseserratus* Wet Meadow (CEGL002024) (Nature Serve 2015)

Biophysical Settings: Central Tallgrass Prairie (BpS 4314210) (LANDFIRE 2009)

Natural Resources Conservation Service – Iowa Plant Community Species List: Prairie, Central Wet-Mesic Tallgrass (USDA-NRCS 2007)

Iowa Department of Natural Resources: Clay Loam Tallgrass Prairie (INAI 1984)

U.S. Army Corps of Engineers: Wet to Wet-Mesic Prairies (Eggers and Reed 2015)

## Ecological site concept

Wet Loess Upland Flat Prairies are located within the blue areas on the map (Figure 1). They occur on upland flats and high stream terraces. The soils are somewhat poorly to poorly-drained and deep, formed in loess. Low hydraulic gradients create a shallow depth to an apparent water table during the early growing season.

The historic pre-European settlement vegetation on this ecological site was dominated by upland and hydrophytic tallgrass vegetation as the hydric/non-hydric boundary was greatly intermixed. Big bluestem (*Andropogon gerardii* Vitman) and New England aster (*Symphyotrichum novae-angliae* (L.) G.L. Nesom) are the dominant and characteristic grass and forb species, respectively. Other grasses present can include switchgrass (*Panicum virgatum* L.), prairie cordgrass (*Spartina pectinata* Bosc ex Link), Canada wildrye (*Elymus canadensis* L.), and various sedges (Eggers and Reed 2015; NatureServe 2015). Forbs typical of an undisturbed plant community associated with this ecological site include compassplant (*Silphium laciniatum* L.) and marsh pea (*Lathyrus palustris* L.) (Drobney et al. 2001; Eggers and Reed 2015). Shrubs, when present, are widely scattered and may include silky dogwood (*Cornus obliqua* Raf.), white meadowsweet (*Spiraea alba* Du Roi), pussy willow (*Salix discolor* Muhl.), and meadow willow (*Salix petiolaris* Sm.) (Eggers and Reed 2015). Fire is the primary disturbance factor that maintains this site, while herbivory and drought are secondary factors (LANDFIRE 2009).

## Associated sites

R108XC515IA	<b>Ponded Upland Depression Sedge Meadow</b> Loess parent material that is ponded including Sperry soils
R108XC517IA	<b>Wet Loess Upland Flat Savanna</b> Loess parent material that is shallow to the water table and classifies as a Mollic subgroup of an Alfisol including Atterberry, Givin, Rubio, and Walford soils
R108XC503IA	<b>Loess Upland Prairie</b> Loess parent material that is not shallow to a water table including Killduff, Nira, Osco, Otley, Port Byron, Tallula, and Tama soil soils
R108XC506IA	<b>Sandy Upland Prairie</b> Eolian sand parent material including Bolan, Broadwell, Dickinson, Pillot, and Sparta soils

## Similar sites

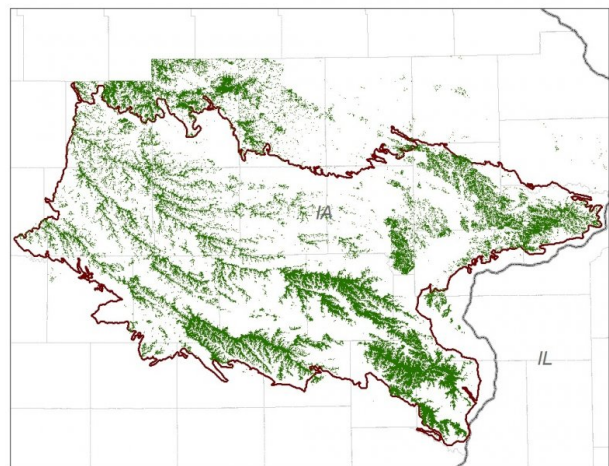
R108XC510IA	<b>Till Backslope Seepage Meadow</b> Till Backslope Seepage Meadows are lower on the landscape and are a SLOPE: stratigraphic, discharge wetland
R108XC515IA	<b>Ponded Upland Depression Sedge Meadow</b> Ponded Upland Depression Sedge Meadows are similar in landscape position but can experience ponding and are DEPRESSIONAL wetlands
R108XC519IA	<b>Wet Upland Drainageway Prairie</b> Wet Upland Drainageway Prairies occur on upland drainageways and are a SLOPE: topographic, flow-through wetland

Table 1. Dominant plant species

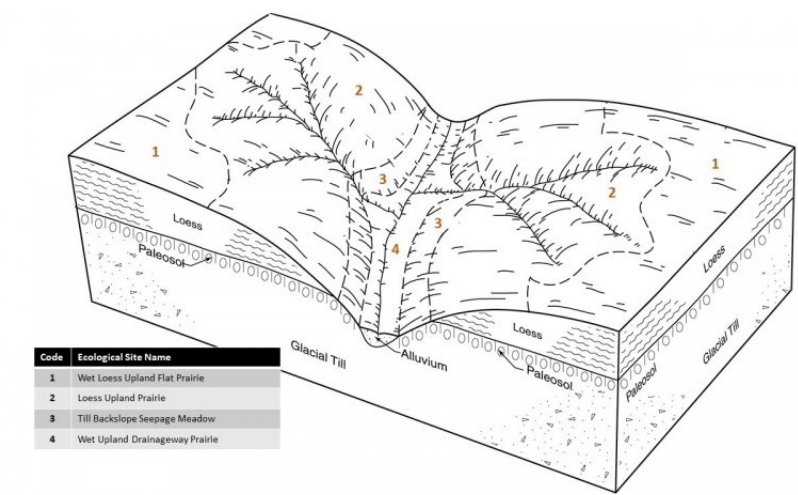
Tree	Not specified
Shrub	(1) <i>Cornus obliqua</i> (2) <i>Spiraea alba</i>
Herbaceous	(1) <i>Andropogon gerardii</i> (2) <i>Symphyotrichum novae-angliae</i>

### Physiographic features

Wet Loess Upland Flat Prairies occur on upland flats and high stream terraces (Figure 2). They are situated on elevations ranging from approximately 528 to 1401 feet ASL. The site does not experience flooding, but rather allows for groundwater recharge due to low hydraulic gradients.



**Figure 2.** Figure 1. Location of Wet Loess Upland Flat Prairie ecological site within MLRA 108C.



**Figure 3.** Figure 2. Representative block diagram of Wet Loess Upland Flat Prairie and associated ecological sites.

**Table 2.** Representative physiographic features

Slope shape across	(1) Concave (2) Linear
Slope shape up-down	(1) Concave (2) Linear
Landforms	(1) Upland > Flat (2) River valley > Terrace
Runoff class	Low to medium
Flooding frequency	None

Ponding frequency	None
Elevation	528–1,401 ft
Slope	0–5%
Water table depth	0–12 in
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 180 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 38 inches, which includes rainfall plus the water equivalent from snowfall (Table 3). The average annual low and high temperatures are 39 and 60°F, respectively.

Climate data and analyses are derived from 30-year averages gathered from five 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)	135-150 days
Freeze-free period (characteristic range)	167-182 days
Precipitation total (characteristic range)	35-37 in
Frost-free period (actual range)	134-152 days
Freeze-free period (actual range)	165-184 days
Precipitation total (actual range)	35-38 in
Frost-free period (average)	142 days
Freeze-free period (average)	174 days
Precipitation total (average)	36 in

## Climate stations used

- (1) IOWA CITY [USC00134101], Iowa City, IA
- (2) WASHINGTON [USC00138688], Washington, IA
- (3) TIPTON [USC00138266], Tipton, IA
- (4) NEWTON [USC00135992], Newton, IA
- (5) WILLIAMSBURG 3SE [USC00139067], Williamsburg, IA

## Influencing water features

Wet Loess Upland Flat Prairies may be classified as a MINERAL SOIL FLATS: saturated, recharge, herbaceous wetland under the Hydrogeomorphic (HGM) classification system (Smith et al. 1995; USDA-NRCS 2008) and as a Palustrine, Persistent Emergent, Seasonally Saturated wetland under the National Wetlands Inventory (FGDC

2013). Precipitation is the main source of water for this ecological site (Smith et al. 1995). Infiltration is very slow to slow (Hydrologic Group C and D) for undrained soils, and surface runoff is low to medium (Figure 5).

Primary wetland hydrology indicators for an intact Wet Loess Upland Flat Prairie may include: A2 High water table and A3 Saturation. Secondary wetland hydrology indicators may include: C2 Dry-season water table and D5 FAC-neutral test (USACE 2010).

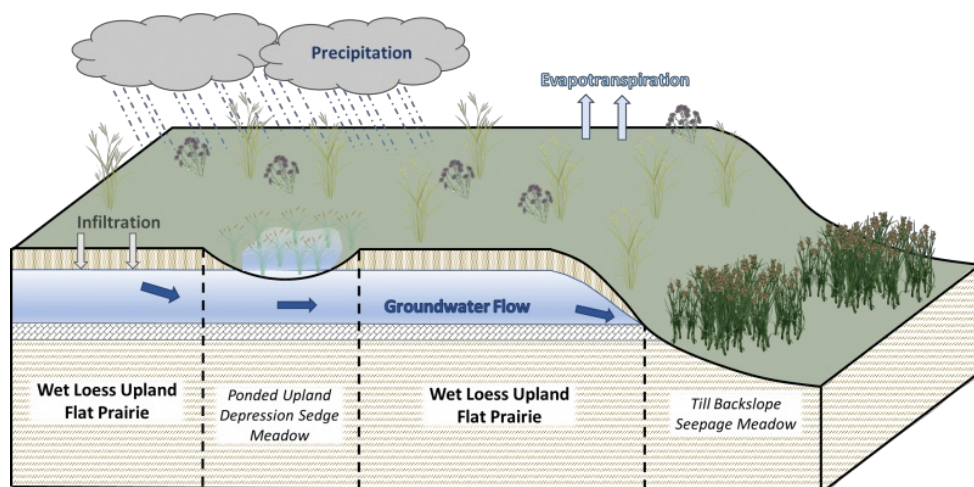


Figure 10. Figure 5. Hydrologic cycling in Wet Loess Upland Flat Prairie ecological site.

## Soil features

Soils of Wet Loess Upland Flat Prairies are in the Mollisols order, further classified as Aquertic Argiaquolls, Aquic Hapludolls, Typic Endoaquolls, Vertic Argiaquolls, and Vertic Endoaquolls with very slow to slow infiltration and low to medium runoff potential. The soil series associated with this site includes Garwin, Kalona, Mahaska, Muscatine, and Taintor (Figure 6). The parent material is loess, and the soils are somewhat poorly to poorly-drained and deep with seasonal high-water tables. Soil pH classes are moderately acid to slightly alkaline. No rooting restrictions are noted for the soils of this ecological site (Table 5).

Some soil map units in this ecological site, if not drained, may meet the definition of hydric soils and are listed as meeting criteria 2 of the hydric soils list (77 FR 12234).

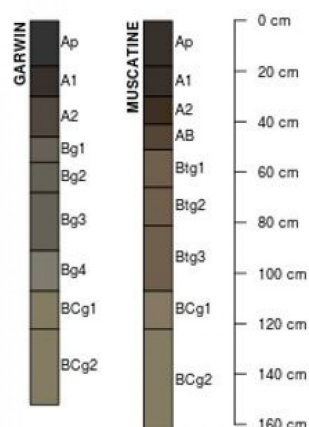


Figure 11. Figure 6. Profile sketches of soil series associated with Wet Loess Upland Flat Prairie.

Table 4. Representative soil features

Parent material	(1) Loess
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Surface texture	(1) Loam (2) Silty clay loam (3) Silt loam
Family particle size	(1) Fine (2) Fine-silty
Drainage class	Poorly drained to somewhat poorly drained
Permeability class	Very slow to slow
Soil depth	80 in
Surface fragment cover <=3"	0%
Surface fragment cover >3"	0%
Available water capacity (Depth not specified)	7–9 in
Calcium carbonate equivalent (Depth not specified)	0–15%
Soil reaction (1:1 water) (Depth not specified)	5.6–7.8
Subsurface fragment volume <=3" (Depth not specified)	0%
Subsurface fragment volume >3" (Depth not specified)	0%

## 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. Wet Loess Upland Flat Prairies form an aspect of this vegetative continuum. This ecological site occurs on upland flats and high stream terraces on somewhat poorly to poorly-drained soils, spanning the hydric/non-hydric boundary. As a result, species characteristic of this ecological site consist of both upland and hydrophytic herbaceous vegetation.

Fire is a critical disturbance factor that maintains Wet Loess Upland Flat Prairies. Fire intensity typically consisted of periodic, low-intensity surface fires occurring every 1 to 3 years (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).

Drought and herbivory by native ungulates have also played a role in shaping this ecological site. The periodic episodes of reduced soil moisture in conjunction with the somewhat poorly to poorly-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. Bison (*Bos bison*) grazing, while present, served a more limited role in community composition and structure than lands further west. Prairie elk (*Cervus elaphus*) and white-tailed deer (*Odocoileus virginianus*) likely contributed to woody species reduction but are also considered to be of a lesser impact compared to the west (LANDFIRE 2009). When coupled with fire, periods of drought and herbivory can further delay the establishment of woody vegetation (Pyne et al. 1996).

Today, Wet Loess Upland Flat Prairies have been greatly reduced as most areas have been converted to agricultural production. Corn (*Zea mays* L.) and soybeans (*Glycine max* (L.) Merr.) are the dominant crops grown, but small patches of forage land may be present. Remnants that do exist show evidence of indirect anthropogenic influences from fire suppression, subsurface drainage, and non-native species invasion. A return to the historic plant

community may not be possible following extensive land modification, but long-term conservation agriculture or prairie 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 wet-mesic tallgrass community, dominated by both upland and hydrophytic vegetation. The two community phases within the reference state are dependent on periodic fire. The intensity and frequency alter species composition, cover, and extent, while regular fire intervals keep woody species from dominating. Drought and native mammal grazing have more localized impacts in the reference phases, but do contribute to overall species composition, diversity, cover, and productivity.

Community Phase 1.1 Silky Dogwood – White Meadowsweet/Big Bluestem – New England Aster – Sites in this reference community phase are dominated by a mix of grasses and forbs with patchy shrubs. Vegetative cover is continuous (95 to 100 percent) and plants can reach heights between 3 and 6 feet tall (LANDFIRE 2009; NatureServe 2015). Big bluestem, switchgrass, Canada wildrye, prairie cordgrass, and various sedges are the dominant monocots on the site. Characteristic forbs can include New England aster, Virginia mountainmint (*Pycnanthemum virginianum* (L.) T. Dur. & B.D. Jacks. ex B.L. Rob. & Fernald), sawtooth sunflower (*Helianthus grosseserratus* M. Martens), hairy hedgenettle (*Stachys pilosa* Nutt.), and giant goldenrod (*Solidago gigantea* Aiton) (Eggers and Reed 2015; NatureServe 2015). Silky dogwood, white meadowsweet, pussy willow, and prairie willow can be widely scattered. Fire with low intensity will maintain this community phase, but a hot, replacement fire will shift the site to community phase 1.2 (LANDFIRE 2009).

Pathway 1.1A – Hot, replacement fire every 1 to 3 years.

Community Phase 1.2 Big Bluestem – New England Aster – This reference community phase represents a successional shift following a major fire event. A high intensity fire will remove much of the scattered shrub layer as well as accumulated plant litter. The wet-mesic tallgrass prairie continues to be dominated by various upland and hydrophytic herbaceous grasses and forbs. Vegetative regrowth following the fire is rapid with plants reaching maximum heights by the end of the first growing season. A couple years without fire allows the community to mature and shrubs to mature, shifting the site back to phase 1.1 (LANDFIRE 2009).

Pathway 1.2 – Natural succession as a result of a brief fire-free period.

Transition 1A – Long-term fire suppression transitions the site to the fire-suppressed scrub 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 SCRUB STATE

Long-term fire suppression can transition the reference tallgrass prairie community into a woody-invaded shrub-prairie state. This state is evidenced by a well-developed shrub layer and sparse trees (LANDFIRE 2009). Proximity to lands that have been altered provide opportunities for non-native invasive species to readily colonize this state, thereby reducing the native biodiversity and changing the vegetative community.

Community Phase 2.1 Green Ash – Silky Dogwood/Big Bluestem – Smooth Brome – This community phase represents the early stages of long-term fire-suppression. In as little as six fire-free years, the prairie can be disrupted and succeeded by woody shrubs. Native trees – e.g., green ash (*Fraxinus pennsylvanica* Marshall), silver maple (*Acer saccharinum* L.), elm (*Ulmus* L.) – and shrubs can form dense thickets with cover reaching up to 30 percent and plant heights as tall as 9 feet (LANDFIRE 2009). Some native prairie plants will persist, but non-native herbaceous species, including smooth brome (*Bromus inermis* L.), Kentucky bluegrass (*Poa pratensis* L.), and redtop (*Agrostis gigantea* Roth) can begin to encroach from adjacent, disturbed sites.

Pathway 2.1A – Continued fire suppression in excess of 20 years.

Community Phase 2.2 Green Ash – Silver Maple/Silky Dogwood/Smooth Brome – Kentucky Bluegrass – Sites falling into this community phase have a well-established shrub layer, and scattered trees begin to develop in the continued absence of fire.

Transition 2A – Single large disturbance event such as selective removal of some woody species.

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 wet-mesic prairie state (5).

### STATE 3 – FORAGE STATE

The forage state occurs when the site 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 scrub 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 wet-mesic prairie state (5).

## STATE 4 – CROPLAND STATE

The low topographic relief of this ecological site has resulted in nearly the entire area being converted to agriculture (Eilers and Roosa 1994). Subsurface drainage and the continuous use of tillage, row-crop planting, and chemicals (i.e., herbicides, fertilizers, etc.) have 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 scrub 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 wet-mesic prairie state (5).

## STATE 5 – RECONSTRUCTED WET-MESIC PRAIRIE STATE

Prairie reconstructions have become an important tool for repairing natural ecological functions and conserving biodiversity. Because the historic plant and soil biota communities of the tallgrass prairie were highly diverse with complex interrelationships, historic prairie 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 wet-mesic prairie state is the result of a long-term commitment involving a multi-step, adaptive management process. Diverse, species-rich seed mixes are 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 can 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, and a few shrubs. Establishing a prescribed fire regimen 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 woody vegetation (Brudvig et al. 2007).

Community Phase 5.1 Early Successional Reconstructed Wet-Mesic Prairie – This community phase represents the early community assembly from prairie reconstruction and is highly dependent on hydroperiod repair, a diverse seed mix, and the timing and priority of planting operations. The seed mix should look to include a diverse mix of cool-season and warm-season annual and perennial grasses and forbs typical of the reference state (e.g., big bluestem, switchgrass, prairie cordgrass, New England aster). Cool-season annuals can help 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.

Pathway 5.1A – Selective herbicides are used to control non-native species, and prescribed fire and/or light grazing helps to increase the native species diversity and control woody vegetation.

Community Phase 5.2 Late Successional Reconstructed Wet-Mesic Prairie – 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 prairie communities are dominated by grasses, these species can suppress forb establishment and reduce overall diversity and ecological function (Martin and Wilsey 2006; Williams et al. 2007). Reducing accumulated plant litter from perennial bunchgrasses allows more light and nutrients to become available for forb recruitment, allowing greater ecosystem complexity (Wilsey 2008).

Pathway 5.2A – 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).

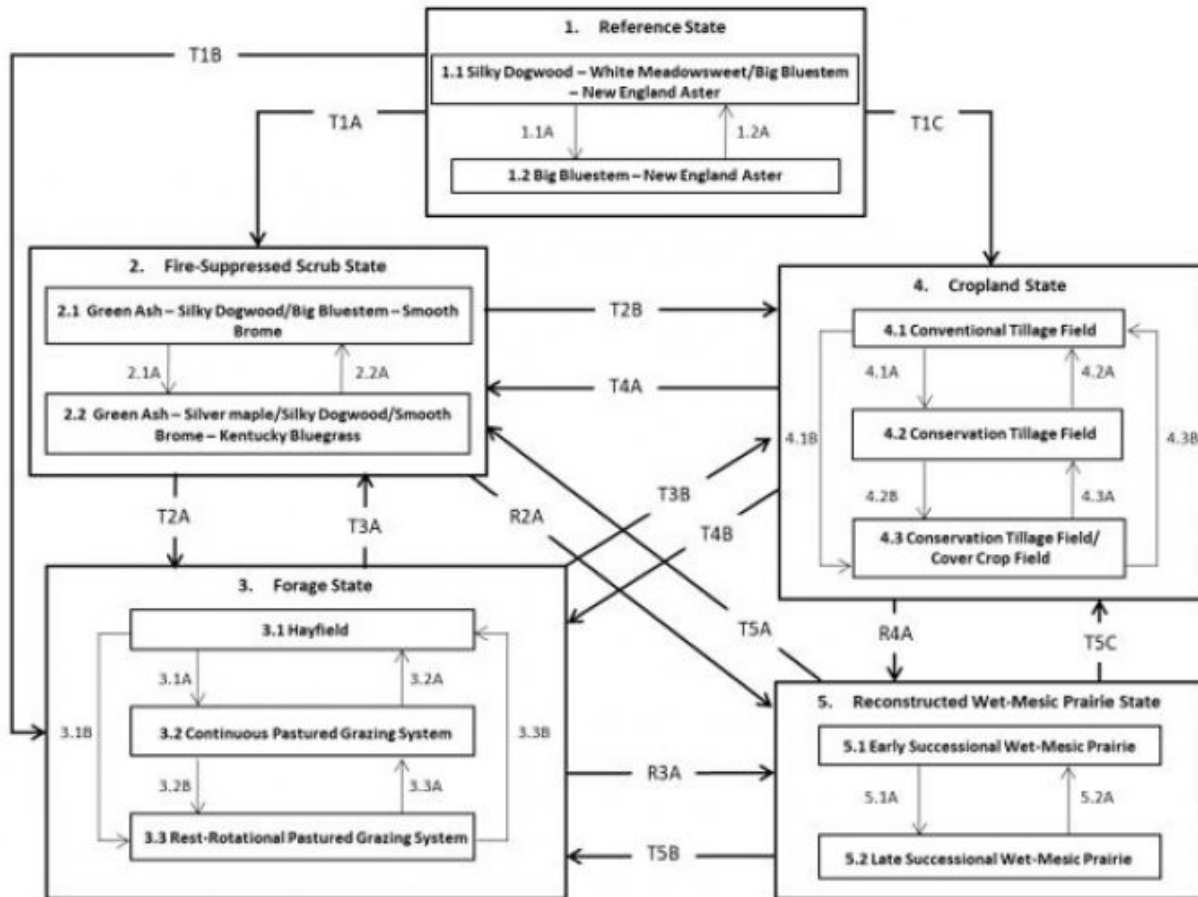
Transition 5A – Land abandonment transitions the site to the fire-suppressed scrub state (2).

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

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

## **State and transition model**

## R108CY5161A WET LOESS UPLAND FLAT PRAIRIE



Code	Process
1.1A	Hot, replacement fire every 1 to 3 years
1.2A	Natural succession as a result of a brief fire-free period
T1A, T3A, T4A, T5A	Long-term fire suppression and/or land abandonment
2.1A	Continued fire suppression in excess of 20 years
2.2A	Single large disturbance event
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

### State 1 Reference State

The reference plant community is categorized as a wet-mesic tallgrass community, dominated by both upland and hydrophytic vegetation. The two community phases within the reference state are dependent on periodic fire. The intensity and frequency alter species composition, cover, and extent, while regular fire intervals keep woody species from dominating. Drought and native mammal grazing have more localized impacts in the reference phases, but do

contribute to overall species composition, diversity, cover, and productivity.

## **Community 1.1**

### **Silky Dogwood – White Meadowsweet/Big Bluestem – New England Aster**

Sites in this reference community phase are dominated by a mix of grasses and forbs with patchy shrubs. Vegetative cover is continuous (95 to 100 percent) and plants can reach heights between 3 and 6 feet tall (LANDFIRE 2009; NatureServe 2015). Big bluestem, switchgrass, Canada wildrye, prairie cordgrass, and various sedges are the dominant monocots on the site. Characteristic forbs can include New England aster, Virginia mountainmint (*Pycnanthemum virginianum* (L.) T. Dur. & B.D. Jacks. ex B.L. Rob. & Fernald), sawtooth sunflower (*Helianthus grosseserratus* M. Martens), hairy hedgenettle (*Stachys pilosa* Nutt.), and giant goldenrod (*Solidago gigantea* Aiton) (Eggers and Reed 2015; NatureServe 2015). Silky dogwood, white meadowsweet, pussy willow, and prairie willow can be widely scattered. Fire with low intensity will maintain this community phase, but a hot, replacement fire will shift the site to community phase 1.2 (LANDFIRE 2009).

## **Community 1.2**

### **Big Bluestem – New England Aster**

This reference community phase represents a successional shift following a major fire event. A high intensity fire will remove much of the scattered shrub layer as well as accumulated plant litter. The wet-mesic tallgrass prairie continues to be dominated by various upland and hydrophytic herbaceous grasses and forbs. Vegetative regrowth following the fire is rapid with plants reaching maximum heights by the end of the first growing season. A couple years without fire allows the community to mature and shrubs to mature, shifting the site back to phase 1.1 (LANDFIRE 2009).

## **Pathway 1.1A**

### **Community 1.1 to 1.2**

Hot, replacement fire every 1 to 3 years.

## **Pathway 1.2A**

### **Community 1.2 to 1.1**

Natural succession as a result of a brief fire-free period.

## **State 2**

### **Fire-suppressed State**

Long-term fire suppression can transition the reference tallgrass prairie community into a woody-invaded shrub-prairie state. This state is evidenced by a well-developed shrub layer and sparse trees (LANDFIRE 2009). Proximity to lands that have been altered provide opportunities for non-native invasive species to readily colonize this state, thereby reducing the native biodiversity and changing the vegetative community.

## **Community 2.1**

### **Green Ash – Silky Dogwood/Big Bluestem – Smooth Brome**

This community phase represents the early stages of long-term fire-suppression. In as little as six fire-free years, the prairie can be disrupted and succeeded by woody shrubs. Native trees – e.g., green ash (*Fraxinus pennsylvanica* Marshall), silver maple (*Acer saccharinum* L.), elm (*Ulmus* L.) – and shrubs can form dense thickets with cover reaching up to 30 percent and plant heights as tall as 9 feet (LANDFIRE 2009). Some native prairie plants will persist, but non-native herbaceous species, including smooth brome (*Bromus inermis* L.), Kentucky bluegrass (*Poa pratensis* L.), and redtop (*Agrostis gigantea* Roth) can begin to encroach from adjacent, disturbed sites.

## **Community 2.2**

### **Green Ash – Silver Maple/Silky Dogwood/Smooth Brome – Kentucky Bluegrass**

Sites falling into this community phase have a well-established shrub layer, and scattered trees begin to develop in the continued absence of fire.

### **Pathway 2.1A**

#### **Community 2.1 to 2.2**

Continued fire suppression in excess of 20 years.

### **Pathway 2.2A**

#### **Community 2.2 to 2.1**

Single large disturbance event such as selective removal of some woody species.

## **State 3**

### **Forage State**

The forage state occurs when the reference state is converted to a farming operation 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 and Kentucky bluegrass, 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 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).

### **Community 3.2**

#### **Continuous Pastured Grazing**

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.

### **Community 3.3**

#### **Periodic-rest Pastured Grazing**

This community phase is characterized by periodic-rest grazing where the pasture has been subdivided into several smaller paddocks. Subdividing the pasture in this way allows livestock to 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). Periodic-rest pastured grazing include deferred periods, rest periods, and periods of 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 3.1A**

#### **Community 3.1 to 3.2**

Mechanical harvesting is replaced with domestic livestock utilizing continuous grazing.

### **Pathway 3.1B**

#### **Community 3.1 to 3.3**

Mechanical harvesting is replaced with domestic livestock utilizing periodic-rest grazing.

### **Pathway 3.2A**

#### **Community 3.2 to 3.1**

Domestic livestock are removed, and mechanical harvesting is implemented.

### **Pathway 3.2B**

#### **Community 3.2 to 3.3**

Periodic-rest grazing replaces continuous grazing.

### **Pathway 3.3B**

#### **Community 3.3 to 3.1**

Domestic livestock are removed, and mechanical harvesting is implemented.

### **Pathway 3.3A**

#### **Community 3.3 to 3.2**

Continuous grazing replaces periodic-rest grazing.

## **State 4**

### **Cropland State**

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 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 alternating periods of corn and soybean crops. 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).

### **Community 4.2**

#### **Conservation Tillage Field**

This community phase is characterized by periodically alternating crops and utilizing 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 operations. 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 operations 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 operations, 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.

### **Community 4.3**

#### **Conservation Tillage Field/Alternative 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 row crop operation.

#### **Pathway 4.1A**

##### **Community 4.1 to 4.2**

Tillage operations are greatly reduced, alternating crops occurs on a regular interval, and crop residue remains on the soil surface.

#### **Pathway 4.1B**

##### **Community 4.1 to 4.3**

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

#### **Pathway 4.2A**

##### **Community 4.2 to 4.1**

Intensive tillage is utilized, and monoculture row-cropping is established.

#### **Pathway 4.2B**

##### **Community 4.2 to 4.3**

Cover crops are implemented to minimize soil erosion.

#### **Pathway 4.3B**

##### **Community 4.3 to 4.1**

Intensive tillage is utilized, cover crops practices are abandoned, monoculture row-cropping is established on a more-or-less continuous basis.

#### **Pathway 4.3A**

##### **Community 4.3 to 4.2**

Cover crop practices are abandoned.

### **State 5**

#### **Reconstructed Wet Mesic Prairie State**



Prairie reconstructions have become an important tool for repairing natural ecological functions and conserving biodiversity. Because the historic plant and soil biota communities of the tallgrass prairie were highly diverse with complex interrelationships, historic prairie 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 wet-mesic prairie state is the result of a long-term commitment involving a multi-step, adaptive management process. Diverse, species-rich seed mixes are 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 can 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, and a few shrubs. Establishing a prescribed fire regimen 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 woody vegetation (Brudvig et al. 2007).

## **Community 5.1**

### **Early Successional Reconstructed Wet-Mesic Prairie**

This community phase represents the early community assembly from prairie reconstruction and is highly dependent on hydroperiod repair, a diverse seed mix, and the timing and priority of planting operations. The seed mix should look to include a diverse mix of cool-season and warm-season annual and perennial grasses and forbs typical of the reference state (e.g., big bluestem, switchgrass, prairie cordgrass, New England aster). Cool-season annuals can help 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.

## **Community 5.2**

### **Late Successional Reconstructed Wet-Mesic Prairie**

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 prairie communities are dominated by grasses, these species can suppress forb establishment and reduce overall diversity and ecological function (Martin and Wilsey 2006; Williams et al. 2007). Reducing accumulated plant litter from perennial bunchgrasses allows more light and nutrients to become available for forb recruitment, allowing greater ecosystem complexity (Wilsey 2008).

## **Pathway 5.1A**

### **Community 5.1 to 5.2**

Selective herbicides are used to control non-native species, and prescribed fire and/or light grazing helps to increase the native species diversity and control woody vegetation.

## **Pathway 5.2A**

### **Community 5.2 to 5.1**

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 T1A**

### **State 1 to 2**

Long-term fire suppression transitions the site to the fire-suppressed scrub state (2).

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

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

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

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

**Transition T2A****State 2 to 3**

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

**Transition T2B****State 2 to 4**

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

**Restoration pathway R2A****State 2 to 5**

Site preparation, invasive species control, and seeding native species transition this site to the reconstructed wet-mesic prairie state (5).

**Transition T3A****State 3 to 2**

Land abandonment transitions the site to the fire-suppressed scrub state (2).

**Transition T3B****State 3 to 4**

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

**Restoration pathway R3A****State 3 to 5**

Site preparation, tree planting, invasive species control, and seeding native species transition this site to the reconstructed wet-mesic prairie state (5).

**Transition T4A****State 4 to 2**

Land abandonment transitions the site to the fire-suppressed scrub state (2).

**Transition T4B****State 4 to 3**

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

**Restoration pathway R4A****State 4 to 5**

Site preparation, tree planting, invasive species control, and seeding native species transition this site to the reconstructed wet-mesic prairie state (5).

## **Transition T5A**

### **State 5 to 2**

Land abandonment transitions the site to the fire-suppressed scrub state (2).

## **Transition T5B**

### **State 5 to 3**

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

## **Transition T5C**

### **State 5 to 4**

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

## **Additional community tables**

### **Inventory data references**

Tier 3 Sampling Plot used to develop the reference state, community phases 1.1 and 1.2:

State County Ownership Legal Description Easting Northing

Iowa Muscatine Shield Prairie – Iowa Department of Natural Resources T77N R2W S7 656797 4593817

Iowa Muscatine Greiner Preserve – The Nature Conservancy T78N R2W S34 661141 4598019

## **Other references**

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.

Changes in Hydric Soils Database Selection Criteria. 77 Federal Register 12234 (29 February 2012), pp. 12234-12235.

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 Conterminous United States. USDA Forest Service, General Technical Report WO-76. Washington, DC. 92 pps.

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.

Eggers, S.D. and D.M. Reed. 2015. Wetland Plants and Plant Communities of Minnesota and Wisconsin, Version

3.2. U.S. Army Corps of Engineers, Regulatory Branch, St. Paul District. St. Paul, MN. 478 pps.

Federal Geographic Data Committee. 2013. Classification of Wetlands and Deepwater Habitats of the United States. FGDC-STD-004-2013. Second Edition. Wetlands Subcommittee, Federal Geographic Data Committee and U.S. Fish and Wildlife Service, Washington, D.C. 90 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.

Kardol, 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 4314210 Central Tallgrass Prairie. 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).

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.

Prior, J.C. 1991. Landforms of Iowa. University of Iowa Press for the Iowa Department of Natural Resources, Iowa City, IA. 153 pps.

Skinner, R.H. 2008. High biomass removal limits carbon sequestration potential of mature temperate pastures. *Journal for Environmental Quality* 37: 1319-1326.

Smith, R.D., A. Ammann, C. Bartoldus, and M.M. Brinson. 1995. An Approach for Assessing Wetland Functions Using Hydrogeomorphic Classification, Reference Wetlands, and Functional Indices. U.S. Army Corps of Engineers, Waterways Experiment Station, Wetlands Research Program Technical Report WRP-DE-9. 78 pps.

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.

U.S. Army Corps of Engineers [USACE]. 2010. Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Midwest Region (Version 2.0). U.S. Army Corps of Engineers, Wetlands Regulatory Assistance Program, U.S. Army Engineer Research and Development Center, Vicksburg, MS. 141 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](https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ia/technical/ecoscience/bio/?cid=nrcs142p2_008160). (Accessed 19 January 2018).

United States Department of Agriculture – Natural Resource Conservation Service (USDA-NRCS). 2008. Hydrogeomorphic Wetland Classification: An Overview and Modification to Better Meet the Needs of the Natural Resources Conservation Service. Technical Note No. 190-8-76. Washington, D.C. 8 pps.

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.

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## **Approval**

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## Rangeland health reference sheet

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

Author(s)/participant(s)	
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Approved by	Suzanne Mayne-Kinney
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

## Indicators

### 1. Number and extent of rills:

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### 2. Presence of water flow patterns:

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3. **Number and height of erosional pedestals or terracettes:**
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4. **Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground):**
- 
5. **Number of gullies and erosion associated with gullies:**
- 
6. **Extent of wind scoured, blowouts and/or depositional areas:**
- 
7. **Amount of litter movement (describe size and distance expected to travel):**
- 
8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):**
- 
9. **Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):**
- 
10. **Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:**
- 
11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):**
- 
12. **Functional/Structural Groups (list in order of descending dominance by above-ground annual-production or live foliar cover using symbols: >>, >, = to indicate much greater than, greater than, and equal to):**
- Dominant:
- Sub-dominant:
- Other:
- Additional:
- 
13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):**
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14. **Average percent litter cover (%) and depth ( in):**

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15. **Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production):**

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16. **Potential invasive (including noxious) species (native and non-native). List species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicators, we are describing what is NOT expected in the reference state for the ecological site:**

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17. **Perennial plant reproductive capability:**

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