**11320**

**Central Mixedgrass Prairie**

BpS Model/Description Version: Aug. 2020

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**Vegetation Type**

Herbaceous

**Map Zones**

31, 38

**Model Splits or Lumps**

This Biophysical Setting (BpS) is lumped with 1488.

**Geographic Range**

This mixedgrass prairie system ranges from South Dakota into the Rolling Plains and the Edwards Plateau of Texas. The loessal regions in west-central Kansas and central Nebraska, the Red Hills region of south-central Kansas and northern Oklahoma are all located within this system (NatureServe 2007).

In map zones (MZs) 31 and 39, Central Mixedgrass Prairie (CES303.659) occurs in southwestern MZ39 and northeastern MZ31, in ECOMAP (Cleland et al. 2007) subsections 332Cd and 332Ca (interspersed within sandhills), 332Cc, 332Cf, and 332Ce (Nebraska Loess Hills region), and it is prevalent within Rosebud Sioux Tribe Reservation and eastern portions of Pine Ridge Indian Reservation. It might also be found in portions of 332Ch, but that is questionable since it is more sandhills in that area. It is also found along the western Missouri River corridor north to Pierre and then just blends into shortgrass prairie (ECOMAP subsections 332Da, 332Df, 331Fe, 331Fv). The Central Mixedgrass Prairie is going to encompass part of MZ39 from southern South Dakota and south -- throughout the Central and Southern Great Plains (whereas BpS 1141 Northwestern Mixedgrass Prairie is the Northern version for Northern Great Plains). East of the Missouri River, the mixedgrass prairie extends into ECOMAP section 332D (sand plains in northern part of 332Dg, east of Bassett) in areas of drier, more shallow soils where it blends in with the western edge of the Northern Tallgrass Prairie. It also extends north to Highmore on the east side of the Missouri River. The Sandhills probably indicate the transition to central versus northern.

In MZ38, this BpS occurs in much of the zone although starts to transition to central tallgrass prairie in subsections 251Ha, 251Hb, Hc, Hd, and 251Gc.

**Biophysical Site Description**

Elevations range from 1,200-3,000ft. Temperatures range between extremes of hot summers and cold winters that are typical of a continental climate. This system occurs in the 16-18in precipitation zone. In Nebraska, ECOMAP section 332C, the rainfall is higher than this, ~20in or more east to west in subsections 332Cc, 332Cf, and 332Ce. Most of the precipitation occurs during the growing season. Soils vary but are generally mollisols. Soils in this BpS are formed from a diverse mixture of various sedimentary deposits. These soils range from clayey to loamy with sandy loams present in the western edge. Terrain consists of gently undulating hills to large expanses of flat open ground in central Nebraska; this type occurs on loess soils with very rugged terrain.

**Vegetation Description**

This vegetation type is characterized by the dominance of grasses such as western wheatgrass and little bluestem on thin uplands. This system typically contains grass species such as *Bouteloua curtipendula*, *Schizachyrium scoparium*, *Andropogon gerardii*, *Hesperostipa comata*, *Sporobolus heterolepis*, and *Bouteloua gracilis*, although the majority of the associations within the region are dominated by *Pascopyrum smithii* or *Schizachyrium scoparium*. Isolated patches of *Quercus macrocarpa* also can occur (NatureServe 2007).

This system includes elements from Western Great Plains Shortgrass (BOGR) and Western Great Plains Tallgrass systems (*Andropogon* spp.), but these are probably just micro-sites. Trees are limited to riparian areas and drainages that may be listed under a different BpS. Silver sage may be found in some floodplains. Other woody species include skunk brush sumac and snowberry, but these species are limited in abundance. Wild plum, buffaloberry, and chokecherry are present in limited amounts throughout the area.

**BpS Dominant and Indicator Species**

Species names are from the NRCS PLANTS database. Check species codes at http://plants.usda.gov.

**Disturbance Description**

This area is strongly influenced by wet-dry cycles. Fire, grazing by large ungulates and small mammals such as prairie dogs, and soil disturbances (i.e., buffalo wallows and prairie dog towns) are the major disturbances in this vegetation type. During dry conditions, there would be more grazing near permanent sources of water. During favorable conditions, grazers would graze farther from permanent water sources.

It would be difficult for prairie dogs to move into an area without some kind of mechanism to reduce the vegetation, which could be drought, grazing, or a combination of any. Under higher precipitation periods and with light grazing, grass would grow quickly, and prairie dogs and other native ungulates might not be able to keep the grass low. Heavy ungulate grazing could create the right conditions for the prairie dog stage. Under favorable conditions, the prairie dog towns could even shrink because the vegetation is growing so fast. During dry conditions, short stature vegetation coupled with grazing can create more of a prairie dog community. Dry conditions can also set the stage for fire, which might then homogenize the landscape. Then the regrowth areas would be nutritious and palatable for the grazers. In wet cycles, there is broader grazing, as grazers would venture from permanent sources of water (Jack Butler, USFS, personal communication).

MZs 39 and 40 modelers recognized a varied degree of grazing pre-European settlement due to bison migration and other ungulates. Heavy grazing would move the community back to earlier stages.

Local site heterogeneity occurs on an even smaller scale, such as with bison wallows – which could even create ephemeral wetlands and a mesic situation. Carcasses could even create heterogeneity. There is also patch grazing occurring, repeated re-grazing, which is enhanced by urine deposition, and an increased chance of re-grazing. Patch grazing creates a mosaic. It is possible that fire could homogenize an area from the preceding patch mosaic (Jack Butler, USFS, personal communication).

Historically, there were likely close interactions between fire and grazing since large ungulates (i.e., bison) tend to be attracted to post-fire communities. Average fire intervals are estimated at 5-15yrs, with the average probably 8-10yrs (Guyette et al. 2012). Lightning fires were most common in July and August but probably occurred from about April to September. Seasonality of fires influences vegetation composition. Recurring early-season fires (April-May) tend to favor warm-season species, while late-season fires (August-September) may affect grass species relatively equally. Cool-season grasses begin to cure in mid-June, making fire more likely in late summer than earlier in the growing season. Fires historically could occur at any time of year but most likely more common in late summer if dry and in early fall after frost and then again in early spring prior to green-up. No data or modeling information are available on the maximum or mean fire intensities possible for this vegetation type.

Native American fires were prevalent in and around encampments for the purpose of driving animals and in some instances escaped cooking or warming fires.

Replacement fire in our model does remove 75% of the above-ground cover as assumed in the literature. However, MZs39 and 40 modelers did not think that loss of the above-ground cover by the replacement fire will necessarily induce retrogression back to an earlier seral stage because the main component of dominant grasses remains unharmed to insure the continuity of the seral stage. However, fire will significantly reduce cover for a season or two. Forb species are often more prevalent for the first few years as well.

In his Rapid Assessment (RA) review, Ortmann suggested that, in addition to fire, drought, and grazing, insect outbreaks (Rocky Mountain locust) would have impacted all classes.

From instrumental weather records, droughts average about 1 in every 10yrs, but droughts are often semi-periodic lasting 3-4yrs in 30-40yr cycles.

**Fire Frequency**

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is the central tendency modeled. Percent of all fires is the percent of all fires modeled in that severity class. Minimum and Maximum FIs show the relative range of fire intervals as estimated by model contributors, if known.

**Scale Description**

Fires probably ranged in size from 10s-10,000s of acres. Today, mean fire size on non-public lands is ~200ac per burn (Weir et al. 2015). Between 1984 and 2014, 127 wildfires occurred within the Central Mixedgrass Prairie in MZ31 (MTBS 2016). Between 1984 and 2014, 617 wildfires occurred within the Central Mixedgrass Prairie in MZ38 (MTBS 2016). The largest wildfire was >261,000ac in size, with a mean fire size of ~5,400ac (MTBS 2016). The maximum wildfire size was 77,000ac. Mean fire size was ~6,000ac over these three decades (MTBS 2016). The variation depends on the build-up of fuel, which was influenced by precipitation and grazing. Extent of weather influences (wet-dry cycles) would have been very widespread. In the loess canyon regions and other areas where terrain is rugged, such as along the Missouri River, topography would influence spread of fire.

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**Adjacency or Identification Concerns**

This system is bordered by the shortgrass prairie on its western edge and the tallgrass prairie to the east. In MZs 31 and 39 in some areas, this also transitions in the west to 1141 (Northwestern Mixedgrass Prairie). From South Dakota to North Dakota, there is also tallgrass. Tallgrass is from ECOMAP subsection 251Aa to the East.

This system is also found along the western Missouri River corridor north to Pierre and then just blends into shortgrass prairie. The shortgrass prairie is predominantly western wheatgrass, blue grama, and buffalograss.

It is probably going to be difficult to distinguish Central Mixedgrass Prairie BpS 1132 from Northwestern Great Plains Mixedgrass Prairie BpS 1141. The distinction can probably be done based on soils and geography. Please see Geographic section above for information. Central Mixedgrass 1132 adheres to the Central and Southern Great Plains, whereas Northwestern Great Plains Mixedgrass 1141 adheres to Northern Great Plains. BpS 1141 excludes the sandhills and goes from northern Nebraska and west to central Montana and is bordered on the east by Central Mixedgrass Prairie, 1132. BpS 1141, the northwestern version is probably defined by the Missouri River. See the geographical description for more information. However, BpS 1141 should transition to BpS 1132, which should transition to tallgrass prairie systems. The boundaries of this system are defined by soils and topography, and this system tends to transition gradually into other systems.

The distinction between BpS 1132 and 1141 might also be based on the shift between cool- and warm-season grasses. The difference between BpS 1132 and 1141 is the C3-C4 shift of cool- to warm-season grass species. In BpS 1141, there are more western – festucas, needle and thread, stronger cool season -- component than in BpS 1132.

There are some good examples of mixedgrass prairie still in the Dakotas. There are some well-managed ranches and parks. There is enough public land -- ~3 million acres of national grasslands as well as national parks which are in good condition. There are also some private lands in good condition. There are some shifts in species but perhaps just western wheatgrass and blue grama (Jack Butler, USFS, personal communication).

Current conditions in Loess Hills grassland system is degraded by chronic improper grazing with lots of C3 exotic grasses having replaced former C4 dominants.

Typical to this region is the encroachment of eastern red cedar. Many unmanaged landscapes are becoming totally dominated by red cedar. Differing tribal management practices can influence the degree of encroachment, particularly along the Missouri River. Many introduced species, such as smooth brome, Kentucky bluegrass, Canada thistle, and Japanese brome, are increasing. Sweet clover, biannual, can increase during wet springs. Massive encroachment of other introduced species (i.e., leafy spurge, red cedar). Cheatgrass currently is increasing in portions of this system. Cheatgrass is a winter annual and decreases under spring prescribed fire.

Plowing has occurred today.

Landscape burning was much more prevalent than today by either Native American burning or unsuppressed free burning wildfire.

There might be more of the early successional, shortgrass class (A) on the landscape today, due to introduced species and grazing.

When thinking about similarity or departure from historic or uncharacteristic communities at landscape levels, the following situations might be useful to check mapping results against classification and model logic. The major influences on current vegetation composition and structure in the Great Plains are:

1) Conversion of grassland to cropland.

2) Introduced species, primarily crested wheatgrass, annual bromes, smooth brome, etc., and sweetclover.

3) Shift from midgrass-dominated grassland communities to shortgrass-dominated communities through season-long heavy grazing (departure from historic), if percentage is outside range of variability. Prairie dog towns would fit into this category. This dynamic can be a response to long-term periodic drought as well (departure from historic range). The midgrass to shortgrass change is a shift that has occurred historically in response to fluctuating climate (drought, above normal precipitation cycles) and grazing intensity/recovery. More may be in shortgrass, under current intensive pastoral grazing systems versus migratory grazing patterns that occurred historically. Grazing would shift midgrass communities to shortgrass-dominated communities (Bison may or may not have influenced this, but season-long heavy livestock grazing seems to cause this shift.) So a high percentage of the landscape in shortgrass; midgrass would indicate a departure.

4) Shift from grassland communities to forest, wooded, or shrub-dominated communities in absence of fire (departure or uncharacteristic for grass BpS). This may be a key shift that has occurred or is occurring on the Great Plains along with conversion of rangeland to cropland and planting of introduced grass species (CRP lands). Current CRP practices are native vegetation. Probably more meaningful in terms of fire disturbance relationships than the shortgrass-midgrass shift.

With the exception of areas occupied by prairie dog towns, the characteristic late succession communities should be dominated by midgrass-dominated plant communities. Tallgrass-dominated communities would only occur as unmapped inclusions associated with topo-edaphic positions. Tallgrass-dominated communities include those dominated by prairie sandreed, big bluestem, and Indian grass.

Additionally, from 2017 BpS Review:  
Reviewers noted that this BpS can have multiple fire intensities and that the original model focused only on replacement fire. Swaty added surface fire to Late 1:CLS. It was suggested that other fire types be added to this class; however, this resulted in basically removing that succession class on the landscape. Readers should note the following:

1. Currently invasion by eastern red cedar is profound and a primary management concern (see Wang et al. 2017; Twidwell et al. 2013a and 2013b).
2. Twidwell reminds us that it is possible to kill resprouting species. This is an important consideration when reading models and/or writing management plans.
3. These ecosystems can be very resilient (see Arterburn et al. 2017). For example, Arterburn et al. (2017) found that even after extreme drought and wildfire, the grasslands of the Nebraska Sandhills did not become destabilized as often hypothesized but returned to original biomass.

Additionally, Susanne Hickey of The Nature Conservancy (Iowa Chapter) suggested lumping the MZ 31 and 33 variants of this BpS together due to abiotic factors. We did not do this due to the substantial differences in the BpS models and descriptions. Users should review both descriptions and models if working along the border of these two MZs.

**Issues or Problems**

The model created by MZs 31 and 39 modelers was based upon a composite 26yrs of range management and prescribed fire monitoring on the following Indian Reservations: Lower Brule, Crow Creek, Rosebud, Pine Ridge, Yankton, and land of the Ponca Tribe of Nebraska.

**Native Uncharacteristic Conditions**

**Comments**

This model for MZs 31 was adapted from the model from the same BpS 1132 from MZ30 created by Mitch Iverson, Amy Symstad, and Travis Lipp and reviewed by Steve Cooper, Steve VanFossen, and Eldon Rash. Model for MZs 31 and 39 changed significantly quantitatively. Co-RL for MZs 31 and 39 also made some model tweaks to more similarly match MZ30 model. Review also resulted in quantitative changes, but modelers were consulted to determine if they wanted to change modelership or not.

The model for BpS 1132 for MZ29/30 was adapted from the RA model R4PRMGn Northern Mixedgrass Prairie, created by Cody Wienk and Lakhdar Benkobi and reviewed by David Engle and John Ortmann. The other modeler for MZ30 was Terry Chaplin. The other reviewer was Jim Von Loh. Regional lead for MZ30 also provided input and changes to the model to a great extent. Approval from original modelers/reviewers sought.

Succession Classes

**Mapping Rules**

Succession class letters A-E are described in the Succession Class Description section. Some classes use a leafform distinction where a qualifier is added to the class letter: Brdl (broadleaf), Con (conifer), or Mix (mixed conifer and broadleaf). UN refers to uncharacteristic native or a combination of height and cover that would not be expected under the reference condition. NP refers to not possible or a combination of height and cover which is not physiologically possible for the species in the BpS.

**Description**

Class A 30 Early Development 1 - Open

*Indicator Species*

*Description*

This is the immediate post-disturbance/post-fire stage or the very short-stature vegetation resulting from disturbance or heavy ungulate grazing. The fuels in this class are generally too sparse and/or too short to carry fire.

A variety of forb species such as scarlet globemallow and curlycup gumweed cab are common in this class, and grasses can also be common. This class will have species that are grazing-resistant and low-growing and drought-tolerant.

Common grass species include blue grama, buffalograss, western wheatgrass, and prairie junegrass. Fringed sagebrush can also be a component of this class. Prickly pear, man sage (ARLU), fringed sage, and broom snakeweed occur in this class. Abundance of prickly pear is much higher than in other seral stages. Other species are SPCO and ARPU9.

This class was initially set to succeed to Class B between 3-7yrs. However, reviewers questioned the low range of 3yrs. It would succeed in 3yrs only under favorable conditions -- unless the site is occupied by prairie dogs, and then it would remain as a prairie dog stage. It would increase in size during drought and grazing, and then it would decrease during a wet cycle. It’s a shifting mosaic of prairie dog movement and towns dependent on grazing and wet/dry cycles. If in a prairie dog state, then the class would last longer in order to transition out of it; however, this is accounted for by having a prairie dog disturbance in the model, resetting succession and keeping it in this class. This class was therefore set to succeed to B after 6yrs, as per reviewer comments.

Prairie dogs probably occupied between 15-40% of an area during some time. Class A should probably have between this amount since Class A includes both the prairie dogs and post-disturbance areas. Amount in this class would also vary by distance to permanent sources of water. During dry conditions, there would be more grazing near permanent sources of water. During favorable conditions, grazers would graze farther from permanent water sources. However, it would be difficult for prairie dogs to move into an area without some kind of mechanism to reduce the vegetation, which could be drought, grazing, or a combination of any (Jack Butler, USFS, personal communication).

Data from prairie dog towns (early seral, aka Class A) suggest cover ranges from 0-80%. Height is most valuable measure of difference between early and other seral stages, but height in mixedgrass prairie often is not much greater than 50cm -- resolution of mapping may not be great enough to distinguish among classes.

High, prolonged heavy grazing was modeled as Optional 1. This includes prairie dog impact.

Drought combined with grazing was modeled as Optional 2. Drought alone was modeled as wind/weather stress occurring but not setting it back to the beginning of the stage.

Regular grazing occurs on this class.

Replacement fire occurs. However, reviewer questioned this interval, as this class and fire is driven more by wet/dry cycles. Most of this Class A couldn’t carry a fire if heavy grazing and drought are occurring as well as prairie dogs. Therefore, the interval was lengthened. Fire also doesn’t set this stage all the way back to the beginning, considering the grasses would quickly resprout. It would take fire, grazing, drought to set it all the way back to the beginning.

Drought conditions could force this stage back to bare ground and annuals. Historically, however, there was very little of the component of annuals and shrubs.

*Maximum Tree Size Class*  
None

Class B 67 Mid Development 1 - Open

*Indicator Species*

*Description*

Blue grama, western wheatgrass, needlegrasses, prairie junegrass, upland sedges, and little bluestem are common grasses. In some areas, species such as big bluestem, prairie sandreed are locally common. Western wheatgrass and little bluestem are the most common species as this class ages. In some areas, western wheatgrass forms dense stands.

Common forbs include scurfpea, prairie coneflower, Rocky Mountain beeplant, scarlet globemallow, and dotted gayfeather. Prickly pear, man sage (*Artemisia ludoviciana*), fringed sage, snowberry, and broom snakeweed occur in this class. Also *Agropyron smithii* is present.

Cover in this class would actually range from 40-80%, depending on soils and weather for the year and the addition of the third class to account for abnormally long periods of low fire activity.

Native grazing occurs, maintaining this stage. High, prolonged heavy grazing was modeled as Optional 1.

Replacement fire occurs most of the time, not causing a transition back to the beginning but some of the time causing a transition back to A. After fire, there is probably also heavy grazing.

Drought can also occur, but infrequently causing a transition back to Class A. Regular drought could occur and not cause a transition (not modeled).

With lack of fire, encroachment might occur after this class. Trees (juniper, chokecherry) and shrubs might appear with higher cover. This class was therefore modeled as succeeding within itself but having an alternate successional pathway going to C.

It would be uncharacteristic to have >20% cover of shrubs/trees.

*Maximum Tree Size Class*  
None

Class C 3 Late Development 1 - Closed

*Indicator Species*

*Description*

The transition to Class C would occur due to lack of fire over an extended period of time. This shrubby stage might occur more on the eastern end of the MZs or in areas that are more protected from fire, such as ravines in the deep loess regions.

Shrubs and other climax species would dominate with an understory of fine fuels within the unburned area. Where the successional stage includes shrubs, mixed and surface fires can occur in addition to replacement fires. Each type of fire can result in multiple potential successional pathways due to variability in fire intensity, severity, and spatial extent (Twidwell et al. 2009, 2013).

Grazing occurs that would cause a transition back to B on 2% of the class each year.

Multiple disturbance pathways exist and are determined by the distribution of species on site. The disturbance pathway following fire depends on fire intensity. High-intensity fire can move closed-canopy juniper woodland to an early successional class. Low to moderate fire intensities can result in closed-canopy juniper woodland moving to a mid-development class or remaining in a late development class (Twidwell et al. 2009, 2013). Replacement fire occurs relatively frequently.

*Maximum Tree Size Class*  
None

Model Parameters

Deterministic Transitions

Probabilistic Transitions

Optional Disturbances

Optional 1: heavy prolonged grazing

Optional 2: drought + grazing

References

Arterburn, J.R., Twidwell, D., Schacht, W.H., Wonkka, C.L. and Wedin, D.A., 2017. Resilience of Sandhills Grassland to Wildfire During Drought. Rangeland Ecology & Management.

Benkobi, L. and D.W. Uresk. 1996. Seral Stage Classification and Monitoring Model for Big Sagebrush/Western Wheatgrass/Blue Grama Habitat. In: Barrow, Jerry R.; McArthur, E. Durant; Sosebee, Ronald E.; Tausch, Robin J., (compa.). Proceedings: shrubland ecosystem dynamics in a changing environment; 1996 May 23-25; Las Cruces, NM. Gen. Tech. Rep. INT-GTR-338. Ogden, UT: USDA Forest Service, Intermountain Research Station.

Bragg, T.B. and A.A. Steuter. 1995. Mixed prairie of the North American Great Plains. Trans. 60th No. Am. Wild. & Natur. Resour. Conf. pp. 335-348.

Briggs, J. M., Knapp, A. K., Blair, J. M., Heisler, J. L., Hoch, G. A., Lett, M. S., & McCarron, J. K. (2005). An ecosystem in transition: causes and consequences of the conversion of mesic grassland to shrubland. *BioScience*, *55*(3), 243-254.

Cleland, D.T.; Freeouf, J.A.; Keys, J.E.; Nowacki, G.J.; Carpenter, C.A.; and McNab, W.H. 2007. Ecological Subregions: Sections and Subsections for the conterminous United States. Gen. Tech. Report WO-76D [Map on CD-ROM] (A.M. Sloan, cartographer). Washington, DC: U.S. Department of Agriculture, Forest Service, presentation scale 1:3,500,000; colored

Collins, S.L. and L.L. Wallace (editors). 1990. Fire in North American tallgrass prairies. University of Oklahoma Press, Norman, OK.

Engle, D. M., Coppedge, B. R., & Fuhlendorf, S. D. (2008). From the dust bowl to the green glacier: human activity and environmental change in Great Plains grasslands. In *Western North American Juniperus Communities* (pp. 253-271). Springer New York.

Guyette, R. P., Stambaugh, M. C., Dey, D. C., & Muzika, R. M. (2012). Predicting fire frequency with chemistry and climate. *Ecosystems*, *15*(2), 322-335.

Higgins, K.F. 1984. Lightning fires in North Dakota grasslands and in pine-savanna lands of South Dakota and Montana. Journal of Range Management 37(2): 100-103.

Higgins, K.F. 1986. Interpretation and compendium of historical fire accounts in the Northern Great Plains. USDI Fish and Wildlife Service Resource Publication 161, Washington, D.C., USA.

MTBS Data Access: National Geospatial Data. (2016, April - last revised). MTBS Project (USDA Forest Service/U.S. Geological Survey). Available online: http://www.mtbs.gov/nationalregional/burnedarea.html [2016, April 29].

Nagel, Harold and Vern Plambeck, Editors. 1998. Loess Hills Prairies of Central Nebraska, Platte Valley Review.

NatureServe. 2007. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Databases. Arlington, VA, U.S.A. Data current as of 15 April 2007.

Owensby, C. E., Blan, K. R., Eaton, B. J., & Russ, O. G. (1973). Evaluation of eastern redcedar infestations in the northern Kansas Flint Hills. *Journal of Range Management*, 256-260.

Ratajczak, Z., Nippert, J. B., & Collins, S. L. (2012). Woody encroachment decreases diversity across North American grasslands and savannas.

Singh, J.S., W.K. Lauenroth, R.K. Heitschmidt and J.L. Dodd. 1983. Structural and functional attributes of the vegetation of northern mixed prairie of North America. The Botanical Review 49(1): 117-149.

Twidwell, D., S. D. Fuhlendorf, D. M. Engle, and C. A. Taylor. 2009. Surface Fuel Sampling Strategies: Linking Fuel Measurements and Fire Effects. Rangeland Ecology & Management 62:223–229.

Twidwell, D., S. D. Fuhlendorf, C. A. Taylor, W. E. Rogers, and P. Kardol. 2013a. Refining thresholds in coupled fire-vegetation models to improve management of encroaching woody plants in grasslands. Journal of Applied Ecology 50:603–613.

Twidwell, D., Rogers, W. E., Fuhlendorf, S. D., Wonkka, C. L., Engle, D. M., Weir, J. R., & Taylor, C. A. 2013b. The rising Great Plains fire campaign: citizens' response to woody plant encroachment. *Frontiers in Ecology and the Environment*, *11*(s1).

Wang, J., Xiao, X., Qin, Y., Dong, J., Geissler, G., Zhang, G., Cejda, N., Alikhani, B. and Doughty, R.B., 2017. Mapping the dynamics of eastern redcedar encroachment into grasslands during 1984–2010 through PALSAR and time series Landsat images. Remote Sensing of Environment, 190, pp.233-246.

Weaver, J.E. and F.W. Albertson. 1956. Grasslands of the Great Plains: their nature and use. Johnsen Publishing Company, Lincoln, NE, USA.

Weir J, D Twidwell, CL Wonkka. 2015. Prescribed burn association activity, needs, and safety record: a survey of the Great Plains. Great Plains Fire Science Exchange, 19 pp.

Wright, H.A. and A.W. Bailey. 1980. Fire ecology and prescribed burning in the Great Plains—a research review. USDA Forest Service General Technical Report INT-77. Intermountain Forest and Range Experiment Station, Ogden, UT.