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Resilience of Sandhills Grassland to Wildfire During Drought☆

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ABSTRACT

In the Nebraska Sandhills, one of the largest contiguous grassland ecoregions remaining in North America, sandy textured soils are stabilized by fine root biomass from predominantly warm-season grasses. Concerns over destabilization have led to management that aims to avoid an undesirable state change toward mobile sand dunes. In 2012, the Sandhills experienced extreme drought conditions that coincided with the worst wildfire year on state record. According to state-and-transition models and ecosystem managers, the combination of wildfire and drought conditions should cause a state transition due to a lack of recovery of grassland vegetation and a loss of sand dune stability. To test this hypothesis, we implemented a time-since-fire study to track biomass recovery of Sandhills grassland vegetation following a wildfire on The Nature Conservancy's Niobrara Valley Preserve in burned and unburned areas. Two yr following the wildfire, aboveground herbaceous biomass in burned areas had recovered to levels that did not differ from unburned areas, maintaining the stability of the sand dunes. This provides evidence that counters current land management frameworks that portray Sandhills grassland as highly vulnerable to destabilization when wildfires occur during severe drought conditions.

Introduction

Considerable uncertainty continues to surround the rangeland discipline's depiction of the role of fire and drought as drivers of vegetation change in sandy soil ecosystems. It is often suggested that sandy soil ecosystems are sensitive to destabilization when a disturbance removes aboveground plant biomass, increases bare ground, and heightens the potential for erosion (Muhs and Wolfe, 1999; Forman, 2001; Mason et al., 2004). This presumption is evident in current state-and-transition models. Both the Ecological Site Description Database (ESD, 2011) and LANDFIRE Program (LANDFIRE, 2012) depict a transition from a stable grassland state to a mobile sand dune state following wildfire in drought (Fig. 1). In addition, management in many sandy soil ecosystems like the Nebraska Sandhills—the largest stabilized sand dune in the Western Hemisphere—aims to limit disturbances, such as fire, that expose bare soil due to concerns over broad-scale destabilization (Stubbendieck 1998). This suggests that there is a prevailing hypothesis among managers that has been put into practice in sandy soil ecosystems. Specifically, vegetation will not recover following fire during drought because the combination of fire and drought has overcome the resilience of the existing grassland state and induced a transition to a new stable state characterized by a lack of vegetation and sand mobility.

While there are case studies where grassland vegetation in sandy soils has recovered following wildfire (Arterburn, 2016; Breshears et al., 2016), data have not been collected during extraordinary conditions when system thresholds have the potential to be overcome, leading to a transition to a new state (e.g., following a wildfire during an exceptionally dry period). Following a wildfire in the Nebraska Sandhills that occurred during the worst drought on modern record and which continued 6 months after the wildfire event (precipitation was 72% below the monthly mean in July 2012; HPRCC, 2015), we initiated monitoring to assess whether Sandhills grassland would recover following the wildfire and drought. Similar to other assessments of ecosystem resilience (Folke et al., 2004; Allen et al., 2005; Wonkka et al., 2016), we used biomass recovery to indicate whether the resilience of a vegetated state has been overcome. Here, we report on the recovery status of this Sandhills grassland 2 yr following the wildfire.

Methods

In July 2012, the Fairfield Creek Wildfire occurred in the north-central Sandhills of Nebraska during a 9-mo drought when precipitation levels were 72% below the historical average (HPRCC, 2015). The wildfire burned a portion of The Nature Conservancy's Niobrara Valley Preserve located 43 km northwest of Ainsworth, Nebraska. The Niobrara Valley Preserve includes a 5 217-ha west bison unit and a 3 935-ha east bison unit that have been grazed continuously by independent bison

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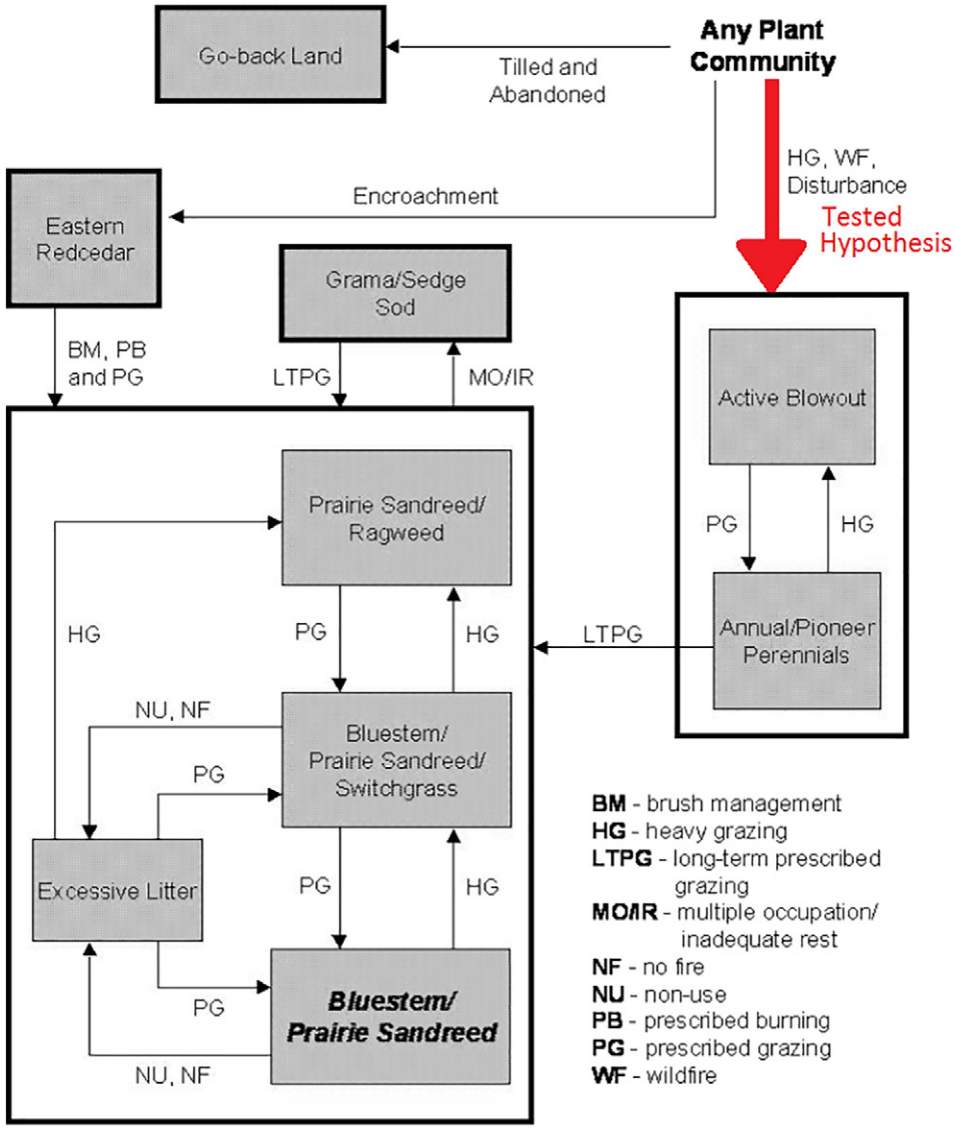

Figure 1. State-and-transition models characterize fire as a disturbance that causes destabilization and a shift to an eroded, sand dune stable state in sandy soil ecosystems. Shown here is an example of a typical state-and-transition model with a transitional pathway from a stabilized grassland state to a mobile sand dune state following wildfire (Sands Medium P.Z. 17—22; MLRA 065-Nebraska Sandhills from the USDA Ecological Site Description Database; ESD, 2011).

herds since 1988 and 1986, respectively. The stocking rate of both units has historically targeted 1 animal unit month (AUM) · ha^{-1} (Pfeiffer and Steuter, 1994), which is low relative to a moderate Sandhills stocking rate of 1.8 AUM · ha^{-1}. Mean annual precipitation for the area is 591 mm, and mean annual temperature is 10°C, ranging from −3°C in January to 24°C in July (HPRCC, 2015). Soils are classified as Valentine fine sands (mixed, mesic Typic Ustipsamments) featuring a low water-holding capacity and a high risk of wind erosion. Upland vegetation at the site is characterized as Sandhills prairie that is dominated by perennial grasses, including sand bluestem (*Andropogon hallii* Hack.), little bluestem (*Schizachyrium scoparium* [Michx.] Nash), and prairie sandreed (*Calamovilfa longifolia* [Hook.] Scribn.).

The Fairfield Creek Wildfire burned major portions of the west (2 281 ha; 43.7%) and east (3 203 ha; 81.4%) bison units in late July 2012, resulting in both burned and unburned areas in each bison unit. At the time of the fire, local weather stations reported temperatures reached 43°C, relative humidity was as low as 13%, and wind gusts were recorded up to 50 km · hr^{-1}. Precipitation levels were 75% below average for the 60 d before the wildfire (HPRCC, 2015). Following the wildfire, departures from the mean annual precipitation in 2013, 2014, and 2015 were −1.73%, −11.48%, and 0.55%, respectively (HPRCC, 2015). Bison continued to have access to burned and unburned areas immediately following the fire at reduced stocking rates of 0.69 AUM · ha^{-1} and 0.49 AUM · ha^{-1}, in west and east bison units, respectively, before increasing to 1.09 AUM · ha^{-1} and 1.12 AUM · ha^{-1} in 2015.

Vegetation Sampling

In 2014, we collected aboveground herbaceous biomass at 3-m intervals along a 300-m, north/south transect, resulting in 100 samples per burned/unburned patch in each bison unit (400 samples total). This sampling was repeated at different locations along the same transect in 2015; however, The Nature Conservancy conducted a prescribed burn that included the unburned portion of the east bison unit, so those samples were not included in our 2015 analysis (resulting in 200 samples in burned areas and 100 in unburned areas in 2015). Transect locations were randomly selected but excluded minor components of the landscape (e.g., patches of trees and shrub islands). While transect sampling can reduce the spatial distribution of the sample, the length of transect used here ensured that the sampling covered a diversity of topoedaphic conditions occurring in the Sandhills. Transects were 10 356 m apart, on average (range: 291—22 687 m). Herbaceous

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