Rangeland Ecology & Management 69 (2016) 76–83

Contents lists available at ScienceDirect

Rangeland Ecology & Management

journal homepage: http://www.elsevier.com/locate/rama

Rangeland Monitoring Reveals Long-term Plant Responses to Precipitation and Grazing at the Landscape Scale☆

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ARTICLE INFO

Article history:
Received 18 February 2015
Received in revised form 27 August 2015
Accepted 1 September 2015

Key words:
Bureau of Land Management
climate and land use change
Colorado Plateau
ecological sites
state-and-transition models
vegetation monitoring

ABSTRACT

Managers of rangeland ecosystems require methods to track the condition of natural resources over large areas and long periods of time as they confront climate change and land use intensification. We demonstrate how rangeland monitoring results can be synthesized using ecological site concepts to understand how climate, site factors, and management actions affect long-term vegetation dynamics at the landscape-scale. Forty-six years of rangeland monitoring conducted by the Bureau of Land Management (BLM) on the Colorado Plateau reveals variable responses of plant species cover to cool-season precipitation, land type (ecological site groups), and grazing intensity. Dominant C_3 perennial grasses *(Achnatherum hymenoides*, *Hesperostipa comata)*, which are essential to support wildlife and livestock on the Colorado Plateau, had responses to cool-season precipitation that were at least twice as large as the dominant C_4 perennial grass *(Pleuraphis jamesii)* and woody vegetation. However, these C_3 perennial grass responses to precipitation were reduced by nearly one-third on grassland ecological sites with fine- rather than coarse-textured soils, and there were no detectable C_3 perennial grass responses to precipitation on ecological sites dominated by a dense-growing shrub, *Coleogyne ramosissima*. Heavy grazing intensity further reduced the responses of C_3 perennial grasses to cool-season precipitation on ecological sites with coarse-textured soils and surprisingly reduced the responses of shrubs as well. By using ecological site groups to assess rangeland condition, we were able to improve our understanding of the long-term relationships between vegetation change and climate, land use, and site characteristics, which has important implications for developing landscape-scale monitoring strategies.

Published by Elsevier Inc. on behalf of Society for Range Management.

Introduction

Rangeland monitoring provides much-needed insight on the condition and trajectory of grassland and shrubland ecosystems. Historical monitoring has often focused on resources of scientific or management concern at the scale of the management unit. However, synthesis of monitoring results at the landscape scale can potentially inform management decisions in the context of the long temporal and broad spatial scales at which much ecological variability exists (Allen and Hoekstra, 1992). Understanding rangeland conditions at these larger scales is particularly important as managers confront and mitigate challenging global change pressures that have broad impacts.

Climate extremes and land use changes are projected to intensify throughout the southwestern United States (Brown et al., 2005; Seager et al., 2007). An early 21st century trend toward increasing temperatures and drought frequency in the southwestern United States is likely to persist (Cayan et al., 2013), thereby stressing already water-limited plant species at a landscape to regional scale. Future increases in human population growth in the southwestern United States (USCB, 2014) will potentially adversely affect rangeland ecosystems through land-use intensification over the long term. In order to mitigate and adapt to these growing pressures, rangeland managers have begun to expand the scope of monitoring (Nusser and Goebel, 1997; Fancy et al., 2009; Toevs et al., 2011). A useful strategy to help managers make informed decisions is to use and learn from long-term rangeland monitoring data.

Our objective is to demonstrate how long-term rangeland monitoring data can be synthesized using ecological site concepts (Herrick et al., 2006) to understand how changes in plant species cover are driven by precipitation and grazing across the landscape. To meet our objective, we compiled long-term (1967–2013) rangeland monitoring data collected by a Bureau of Land Management (BLM) field office in south-central Utah. The BLM manages 105 million ha. of land, primarily in the western United States, and has a long legacy of conducting rangeland vegetation monitoring on plots within grassland and shrubland

☆ This project was funded by the U.S. Geological Survey Status and Trends Program, Data Rescue Program, Climate and Land-Use Program, and support from the Natural Resources Conservation Service.

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http://dx.doi.org/10.1016/j.rama.2015.09.004
1550-7424/Published by Elsevier Inc. on behalf of Society for Range Management.

allotments. The BLM uses ecological site classifications to inform its management decisions and is increasingly reliant on ecological site descriptions to assess rangeland health (Pellant et al., 2005). The ecological site classification system identifies distinctive land types on the basis of specific soil, climate, and landscape factors. Each ecological site has the potential to produce a distinctive kind and amount of vegetation that responds in a predictive way to disturbance and land use (USDA/USDI, 2013; NRCS, 2014). By bridging long-term rangeland monitoring data with ecological site concepts, we provide the context to enhance understanding of vegetation response to climate and land use, which can ultimately inform management decisions and guide future monitoring efforts.

Methods

Site Description

Our study area spans 526 000 ha. of the Colorado Plateau in south-central Utah that is managed by the Hanksville (Henry Mountains) BLM field office (Fig. 1). Sites in our study area range from 1180 to 2020 m in elevation and are bordered on the north by the Wayne-Emery County line, on the west by Capitol Reef National Park, and on the south and east by the Colorado River, Glen Canyon National Recreation Area, and Canyonlands National Park. Mean annual precipitation at our study sites ranges from 150 to 260 mm, with ~45% of annual precipitation falling in the cool season (October to March) and ~35% of annual precipitation falling in the warm season (July-September) (PRISM, 2014). Cool-season precipitation is from limited frontal systems that originate in the Pacific Ocean, while warm-season precipitation is carried from the Gulfs of Mexico and California (Hereford et al., 2002). Maximum mean annual temperatures range from 16.0 to 22.2°C, and minimum mean annual temperatures range from 1.4 to 7.6°C.

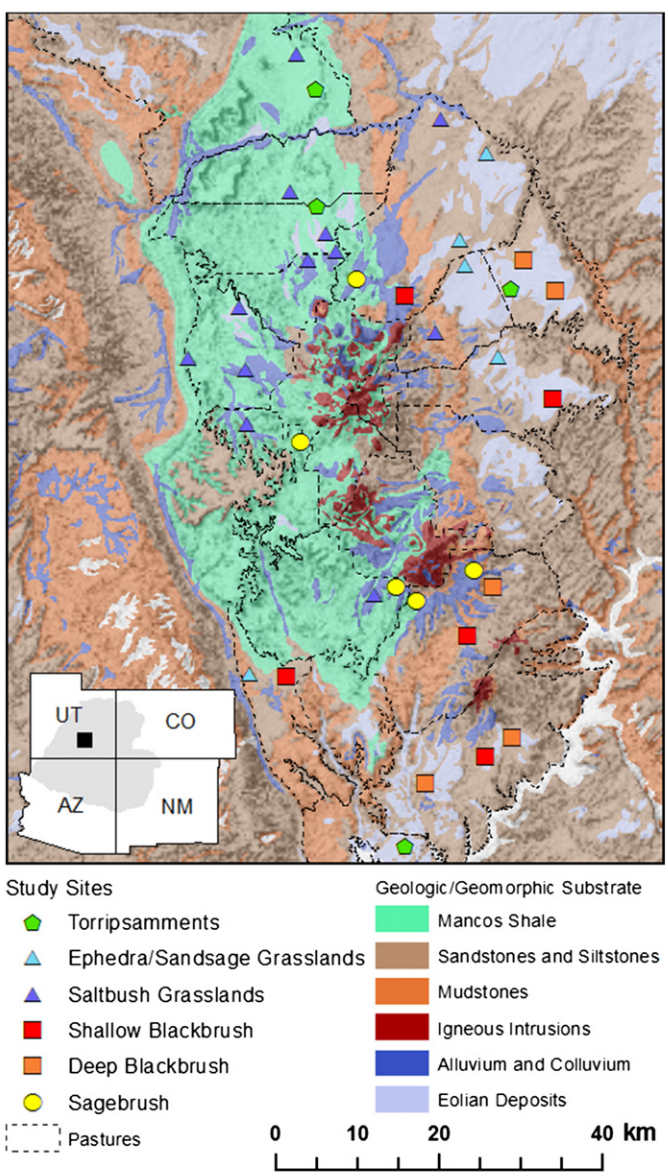

Figure 1. Study sites in south-central Utah on the Colorado Plateau by ecological site group and geologic/geomorphic substrate.

The study area encompasses a range of soil types and associated plant communities due to the variability in elevation and the geologic and geomorphic substrate sampled (see Fig. 1). Two dominant substrate types influence plant community composition and dynamics. The northern and western parts of the study area are underlain by Mancos Shale, a geologic substrate deposited in a deep-water marine environment and characterized by saline chemistry and fine textures. Typical plant species on these soils include saltbushes (*Atriplex* spp.), greasewood *(Sarcobatus vermiculatus)*, and sparsely distributed perennial grasses. Soils in the remainder of the study area are derived primarily from nonsaline sandstones, mudstones, and recently deposited alluvium, colluvium, and eolian sands. Plant species vary widely on these surfaces and include big *(Artemisia tridentata)* and sand *(Artemisia filifolia)* sagebrush, blackbrush *(Coleogyne ramosissima)*, Ephedra species (*Ephedra* spp.), and perennial grasses. Surface textures throughout the study area are sandy, ranging from sands to sandy loams in texture. Subsurface textures are typically finer in soils derived from Mancos Shale or in high-elevation settings (loams and clay loams) than in the other areas (loamy sands to sandy loams).

Grazing by domestic livestock has been ongoing in the region since the 1880s and is still the most extensive land use within the study area (Godfrey, 2008). Grazing permits in the low elevation study area are for cool-season use from October to May (Hanksville BLM, personal communication). Stocking rates, since BLM records began in the 1960s, have ranged from 1500 to 5600 animal unit months on our study allotments (24 000–46 000 ha.). However, like most areas in the western United States, stocking rates were much higher before the Taylor Grazing Act of 1934. Since then, there has been a conversion from predominantly sheep to cattle use and an overall decrease in utilization through time in southern Utah (Godfrey, 2008).

Rangeland Monitoring

Rangeland monitoring was conducted every 1–5 years (except the last measurement, which had a 12-year interval) in late June to September from 1967 to 2013 at 96 permanently marked sites in 15 livestock grazing allotments. Rangeland monitoring consisted of estimating canopy cover of perennial plant species inside permanently marked 1.5 × 1.5 m plots using a frame that was divided into 6 × 6 cm sections. Repeat landscape photographs were taken at the north end of the plot. Nested frequency and point intercept are common range trend methods and were also used at the monitoring site, but preliminary analyses revealed these measurements had extreme variability among years likely due to methodological differences throughout the study period (e.g., frames not placed in the same part of the transect every year, inconsistencies in the number of points read; personal communication with BLM), and therefore we did not further consider these measurements.

The rangeland monitoring data were handwritten in paper format with no global positioning system (GPS) coordinates of transect locations, little metadata, and no site characterization. We converted the paper data into an electronic database to conduct analyses. We chose 36 of the sites that 1) had a minimum of six continuous, repeat measurements taken 1–12 years apart throughout the study period (1967–2013), and 2) were likely to represent a range of ecological