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Synthesis Paper: Assessment of Research on Rangeland Fire as a Management Practice☆

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ABSTRACT

Rangelands are fire-dependent ecosystems severely altered through direct fire suppression and fuels management. The removal of fire is a dominant cause of ecological sites moving across thresholds with the majority of North American rangelands currently showing moderate or high departure from reference conditions. Recognizing the need to restore fire on rangelands and incorporate prescribed fire into management plans, the Natural Resource Conservation Service initiated the Conservation Effects Assessment Project (CEAP) to evaluate the validity current practices through peer-reviewed scientific literature. We updated the CEAP review and broadened the discussion of prescribed fire as a global management practice. We reviewed and summarized prescribed fire literature available through Web of Science using search terms in the title. The majority of literature (40%) evaluated plant responses to fire with fire behavior and management (29%), wildlife and arthropods (12%), soils (11%), and air quality (4%) evaluated less frequently. Generally, fire effects on plants are neutral to positive and the majority of negative responses lasted less than 2 years. Similarly, soil responses were recovered within 2 yr after burning. However, most studies did not report how long treatments were in place (62%) or the size of experimental units (52%). The experimental literature supporting prescribed burning is in need of greater managerial relevance that can be obtained by directly addressing spatial scale, temporal scale, and interaction with other disturbances, including drought and grazing. Reliance on information from single fires applied on small plots tracked for a relatively short time interval greatly constrains inferences and application to ecosystem management and information should be applied with caution. Therefore, conservation purposes need to incorporate temporal dynamics to the extent that this information is available. The complex interaction of scientific knowledge, social concerns, and variable policies across regions are major limitations to the successful and critical restoration of fire regimes.

Introduction

Fire has played a key role in the formation of most rangeland ecosystems in North America (Axelrod, 1985) and the world (Bond et al., 2003; Keeley and Rundel, 2005). Alteration of fire regimes on US rangelands since European settlement has created cases of severely altered ecosystems that can eventually result in no-analog, novel, or emerging ecosystems (House et al., 2003; Hobbs et al., 2009). According to LANDFIRE (an interagency vegetation, fire, and fuel characteristics mapping program sponsored by both the US Departments of Interior and Agriculture), three-fourths of US lands dominated by native plants show moderate or high departure from reference conditions as a result of altered fire regimes (The Nature Conservancy, 2009). Because most rangelands are considered fire-dependent ecosystems, restoring historical fire regimes is fundamentally important when the management goal is to restore or maintain the potential (or historical) natural community. The historical plant community for most ecological sites was maintained by fire, and altered fire regimes are a dominant cause of ecological sites moving across a threshold of increased woody plant dominance (Twidwell et al., 2013), leading to reduced livestock production and loss of other ecosystem services such as pollination (Chi and Molano-Flores, 2015) and soil stabilization (Puttock et al., 2014). Rapid and extensive woodland expansion on rangelands clearly reflects the essential role of fire in the maintenance of historical rangeland ecosystems (Archer, 1994; Limb et al., 2010).

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However, implementation of prescribed burning as a conservation practice in the rangeland management profession has been overshadowed by implementation of other practices, especially prescribed grazing. Disproportionate implementation of these two categories of practices is influenced by the complexity of social interactions among agencies, public perception of risk versus reward, and public policy (Twidwell et al., 2015). Social and policy concerns differ greatly across rangeland regions, ranging from complete acceptance in fire cultures (e.g., Flint Hills of Kansas and Oklahoma) to attempts to completely remove fire from the landscape (e.g., Great Basin).

With few exceptions, fire regimes in grassland ecosystems are altered through intentional fire suppression and by grazing that uniformly reduces fuel loads. In the Great Basin, reduction of fine fuels through grazing have also reduced fire occurrence in the wetter and cooler sagebrush communities where fuels would be otherwise sufficient to carry fire (Miller et al., 2011; Balch et al., 2013). In contrast, the warmer and drier sagebrush communities that are invaded by exotic annual grasses display fine-scale fuel homogeneity, which enables more frequent fire. State-and-transition models suggest conversions to woody plant dominance and to exotic annuals can eventually become irreversible and result in alternative stable states (Twidwell et al., 2013).

Rangeland ecosystems are characterized generally as working landscapes and are subject to diverse management, often to meet economic objectives. However, management of rangeland ecosystems is increasingly difficult with the growing demand for goods and services coupled with declining rangeland area (Anderson and Inouye, 2001; Fischer and Lindenmayer, 2007). Conserving historic species and processes, while maintaining economic stability, requires management practices that are consistent with historic disturbances (Limb et al., 2011b), although exceptions exist where ecosystems have crossed ecological or social threshold boundaries (Davies et al., 2009; Limb et al., 2014).

The Natural Resource Conservation Service (NRCS) commissioned the Conservation Effects Assessment Project (CEAP) to determine if conservation practices align with current science. The rangeland CEAP addressed the need to evaluate current rangeland management practices and broadly assess the impact of management activities on environmental parameters and rangeland conservation. Prescribed burning (Prescribed Burning, Code 338) was one of the NRCS National Conservation Practice Standards (USDA NRCS, 2015a) evaluated through peer-reviewed scientific literature. A complete evaluation of the standard is available (Briske, 2011). Herein, we update the recent review of prescribed fire as a land management practice (Fuhlendorf and Engle, 2001), include a subset of the National Handbook of Conservation Practices (NHCP) standards, and discuss fire in the context of a global management practice.

Defining Our Literature Database

Rangeland ecosystems across the globe vary substantially by climate, soil type, floral and faunal composition, as well as goods and services produced. Given the broad disparity of rangeland ecosystems across the globe, we analyzed the research literature to establish the ecological effects of prescribed fire as a management practice on rangelands. We intentionally took a broad perspective to include research articles on plants, soil, water, wildlife, arthropods, livestock, fire management, fire behavior, smoke management, socioeconomics, air quality, fire history, and human health. We also addressed spatial scale and temporal scale of field studies and other descriptions of field studies (private or public land, grazing status, and ecosystem type) that compose the body of rangeland fire research and then related our findings to the practice of prescribed burning on rangeland.

Evaluation of the peer-reviewed literature on prescribed fire first required determining methods to query the entire body of scientific literature on the topic. We wanted to include all relevant papers, but we limited the scope of the search to exclude fire research from forested ecosystems, which dominates the fire research literature. Many papers that report fire research on rangelands do not include the term *prescribed,* and many relevant papers do not use the term *rangeland.* The data set built from the search with the term *prescribed fire* indicated that numerous important papers were omitted from the pool, and many of the papers included some discussion of fire but with minimal or no data related to fire. Therefore, our final search used the term *fire*, which also located articles with *prescribed fire* in the title, to broaden the search. Although this approach likely excluded some papers that reported research from regionally important ecosystem types (e.g., shinnery oak or chaparral vs. shrubland) and papers in which the title contained other key fire-related words (e.g., burned, burning, and prescribed burning) but not fire, the search located more than 1 000 papers. We do not believe that this is an exhaustive dataset, but we argue that it provides an adequate, unbiased sample from which we could determine the nature of information available through the peer-reviewed literature. Because fire can both positively and negatively influence certain components of ecosystems, fire should be evaluated to address a broad array of ecosystem components. We evaluated and summarized the entire dataset from a global perspective, and for this article, we narrowed the focus to North American rangeland regions to illustrate differences and similarities on key topics. As with the comprehensive search, we used Web of Science to search for papers on a particular topic. We justified limiting our search to these topics on the basis that indexed articles are widely accepted as scientifically valid peer-reviewed literature.

Of the 1 039 papers (available in October 2015) from our query through Web of Science, 846 papers were accessible and confirmed to be peer-reviewed research papers (Appendix 1). Of these 846 papers, fewer than 10 papers were published annually from 1967 through 1989, which was followed by an exponential increase with 50 or more papers published each year from 2009 to 2014 (Fig. 1). In contrast, when we replaced the search term “fire” with “grazing,” more papers were available (14 912), but the increase was linear rather than exponential for the same time period. This suggests that the research community may view fire with increasing importance.

Evaluation of the Dataset

An important outcome of the search was that rangeland fire research literature is dispersed among numerous ecosystems and across most continents. More than 270 journals published rangeland fire research, with studies primarily located in North America (48%), but substantial research was conducted in Africa (14%), Australia (14%), and Europe (11%). Fewer studies were conducted in Asia and South America (5% and 8%, respectively). The majority of papers reported research on plants, fire management, soils, fire behavior, socioeconomics, and wildlife (Table 1). Authors described their papers as addressing a variety of

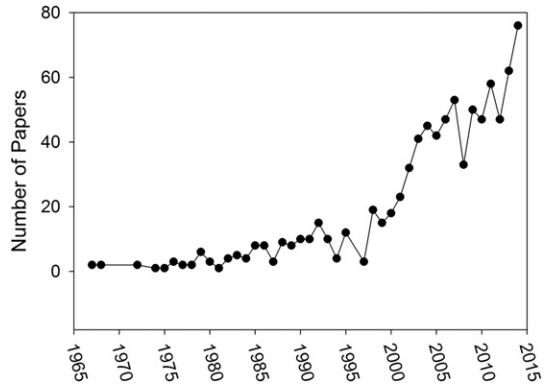

Figure 1. Number of papers published per year from a total of 846 papers published on rangeland fire between 1967 and 2014. See text for an explanation of papers selected.

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