

Fire Ecology and Management in Grasslands of the American Southwest

(invited paper)

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Many ecologists have indicated that fire is as important as wind or precipitation in shaping North American ecosystems. There is little question that fire is prevalent in grasslands and that it contributes to the structure and function of such systems in the Southwest. In this paper I outline pre-settlement fire regimes, then describe post-settlement regimes and vegetation response to fire. I conclude by describing the potential for applying fire to these systems, many of which have not experienced fire for many years. This overview draws heavily from Wright and Bailey (1982) and McPherson and Weltzin (2000).

Humphrey (1958) reviewed historical accounts dating back to 1528 and concluded that fire was prevalent and widespread in Southwestern grasslands at the time of, and shortly after, Anglo settlement. Wright and Bailey's (1982) book summarizes the considerable indirect evidence and agrees with Humphrey's assessment. Evidence from adjacent ecosystems, for example, fire scars on tree rings from ponderosa pine forests upslope from Southwestern grasslands, also supports this interpretation. The cumulative indirect and direct evidence indicates an average fire-return interval of about 5-15 years, depending on site characteristics. Frequency probably was directly related to site productivity, such that increased available soil moisture and nitrogen input contributed to increased incidence of fire. Thus, sites with more frequent fires also had higher precipitation and nitrogen inputs, such that relatively frequent fires did not pose a threat to site productivity in the absence of large herbivores.

Fine fuel accumulation probably was the primary constraint on fire spread in grassland systems before Anglo settlement, rather than ignition sources. In Southwestern grasslands, fuel moisture drops annually during an extended dry period that coincides with plentiful lightning at the leading edge of the summer monsoon. After Anglo settlement, fire spread became limited by availability of fine fuel as livestock removed grass. A national policy of fire suppression also depressed fire frequency in these systems. Today fire spread remains limited by the paucity of fine fuel, as mediated by livestock grazing, in most of the region's grasslands.

Fire effects on vegetation have been summarized in several recent publications (notably, McPherson and Weltzin 2000). With woody plants, there is a highly variable response that is species- and site-specific. Even within a species and site, response depends on growth stage and size of woody plants. Response of herbaceous plants tends to be strongly dependent on post-fire precipitation; if post-fire precipitation is high, herbaceous response will be quite rapid. If post-fire precipitation is average or below average, herbs may not achieve pre-burn productivity until above-average precipitation returns; this recovery may require several years.

These generalizations are tempered by many exceptions and the fact that nearly all of the research on fire ecology in Southwestern grassland ecosystems was conducted over 30 years ago. As such, most of this research lacks modern experimental design and analysis. In addition, the physical and biological environments characterizing these systems have changed within the last few decades. Finally, there have been dramatic changes in socio-economic goals and objectives in these systems. I briefly describe some of these changes to illustrate the point that the world has changed markedly from the one that researchers described in the 1950s, 1960s, and 1970s.

From a strictly physical standpoint, we are observing increases in global and regional temperatures. Since the industrial revolution we have witnessed profound, and recently exponential, increases in temperature variation. We are beginning to see changes in timing of frost, high temperatures, low temperatures, precipitation seasons, and other extreme events, and these certainly will have ramifications for ecosystem structure and function. So, in addition to well-described direct effects of changes in atmospheric chemistry on C_3 versus C_4 plants (i.e., increased atmospheric CO_2 concentrations tend to favor the former at the expense of the latter), we also observe indirect effects that are mediated through changes in climate (McPherson and Weltzin 2000).

Increased fragmentation has characterized Southwestern ecosystems. Grasslands, particularly in the southwestern United States, are "ground zero" for human development. The grasslands lie immediately below

protected Forest Service land, but at a sufficiently high elevation that they experience relatively mild climates, thus representing a prime target for human occupation. Urban development and the associated fragmentation undoubtedly have large consequences for these systems, particularly with respect to hydrology and fire, but these impacts remain poorly documented.

Livestock numbers have decreased substantially in the last century, down to about 20% of estimates for the early 1900s. These decreases in large herbivores within the last 100 years still represent considerably more livestock than were present before Anglo settlement. In addition, negative impacts of livestock on site productivity may persist for several decades.

The increase in abundance of nonnative grasses represents another biological change in these systems. In southeastern Arizona, the dominant nonnative plant is *Eragrostis lehmanniana* (Lehmann lovegrass). Diversity of herbaceous species declines with increased abundance of lovegrass (McPherson et al. 2002). Unfortunately, we do not understand causality in this case; we don't know if lovegrass is invading areas of low diversity, or if lovegrass is causing these declines in diversity. In any event, Southwestern grasslands now contain plenty of lovegrass, buffel grass, and many other species that were not present at the time of Anglo settlement. These "new players" have created systems that are different from the systems that were present in the pre-settlement era and also different from the systems that were studied in the 1950s through the mid-1970s, when most of the research on fire ecology was conducted.

The spread of nonnative plants over the last three to five decades has helped to overcome the fine-fuel constraint on fire. These grasses produce more biomass than native grasses, especially during dry years; the biomass is highly lignified, so it decomposes relatively slowly (McPherson 1997 and references therein). It is available as fuel for a longer period of the year than most native grasses, and, as a result, the increased fuel associated with these nonnative grasses contributes to increased fire spread, since fuel is the most dominant constraint in these systems. The dominant nonnative grasses respond favorably to fire, which contributes to this positive feedback cycle among the presence of these grasses, accumulation of fuel, spread of fire, and spread of the grasses.

Perhaps more important than these changes in environmental conditions is a change in perspective. Goals and objectives have changed throughout most of the world, including Southwestern grasslands. For example, the advent of the Society for Conservation Biology in the United States about 15 years ago is evidence of changing values. Our goals have grown beyond consumptive uses, meat and leather, for example, and are typified by the mission statement of the Society for Conservation

Biology, which reads, in part, to "help develop the scientific and technical means for the protection, maintenance and restoration of life on this planet." As a society, we are also interested in biological diversity, as many of the speakers have suggested at this symposium.

Our objectives do not necessarily include the re-creation of historical conditions. For one thing, we have a very poor understanding of what these conditions were. For another, these systems have changed so profoundly that I think it is impossible to try to restore pre-settlement conditions. In addition, our goals do not include grassland "health" and grassland "integrity," because those are undefined, undefinable, and unmeasurable ideas. We need to focus on goals and objectives that can be evaluated, can be measured, and can be repeated over time.

With respect to bringing fire back into these systems, we must have clearly defined goals before we act. Fire is clearly not a panacea—it can be beneficial, depending on specific objectives. Its absence from these systems is disturbing for many of us, but that does not call for broad scale re-introduction of fire without consideration of fire effects, season, and frequency.

It is especially important that we pay greater attention to seasonality than we have in the past. Most managers who have the nerve to re-introduce fire take this step only during periods that fire can be controlled relatively easily. In Southwestern grasslands, this strategy translates to many fires during March and April, a time inconsistent with historical fire regimes. Most fires in this region probably occurred in late June or early July, coincident with the onset of the southwestern monsoon. What are the implications of applying spring fires for species that have evolved in the presence of periodic summer fires? We really don't know, but we shouldn't assume that they are benign.

Finally, it is clear that we should be paying great attention to monitoring efforts. "Adaptive management" has become the law of the land among resource-management agencies in the United States. Yet we cannot adapt management without monitoring. In the absence of information derived from monitoring, we simply don't know what to adapt to or how to adapt to it. Acquisition of relevant information should facilitate progress toward pro-active management that targets productive, diverse grasslands in this region.

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Ecología de Fuego y Manejo de Pastizales en el Sudoeste Norteamericano

(resumen)

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Para muchos ecologistas, el fuego es tan importante como el viento o la precipitación en la formación de los ecosistemas en Norteamérica, y ciertamente es importante para la estructura y función de los pastizales del sudoeste Norteamericano.

Se ha investigado y concluido que el fuego prevalecía y abarcaba áreas extensas al momento de la colonización europea, y aún poco tiempo después. El fuego era un fenómeno importante en estos sistemas de pastizal. Existe evidencia directa de esto en sistemas adyacentes a los pastizales. La evidencia acumulativa directa e indirecta indica un intervalo promedio de incendio de 5 a 15 años, dependiendo de las características del sitio. Esta frecuencia probablemente se relacionaba con la productividad del sitio, de tal forma que mayor humedad de suelos y mayor suministro de nitrógeno resultarían en una mayor incidencia de fuego.

Antes de la colonización europea, la incidencia de fuego era limitada por la disponibilidad de combustibles finos y no por la abundancia de fuentes de ignición. Los incendios en el sudoeste de los Estados Unidos cesaron al llegar grandes cantidades de ganado con la colonización. La disminución de combustibles finos y la supresión activa de incendios redujeron dramáticamente la frecuencia de los incendios. Las consecuencias de este cambio en frecuencia y de la reintroducción del fuego en estos sistemas son inciertas.

La introducción de especies de pasto no nativas en las últimas décadas ha servido para aumentar el combustible disponible para los incendios, estas especies producen más biomasa que se descompone más lentamente, haciéndola disponible como combustible durante más tiempo. Esto sugiere un ciclo de retroalimentación positiva, porque el pasto no nativo responde favorablemente al fuego.

La respuesta de la vegetación al fuego es altamente variable y dependiente al lugar y especie en particular. En plantas maderables, esta depende de la etapa de crecimiento de la planta, mientras que en herbáceos, depende de la cantidad de precipitación después de un incendio. Si la precipitación es alta la respuesta será bastante rápida. Pero cuando la precipitación es promedio o abajo del promedio, puede ser que los herbáceos no recuperen la productividad que tenían antes del incendio

hasta que llueva abundantemente de nuevo, y eso puede tardar varios años.

Sin embargo, estas generalizaciones presentan muchas excepciones porque la mayoría de estas investigaciones se hicieron hace más de 30 años. Además, el ambiente físico y biológico que caracteriza a estos sistemas ha cambiado en las últimas décadas.

Desde una perspectiva física, el mundo ha cambiado dramáticamente. Las temperaturas globales y regionales aumentan, además de la variación en temperaturas. También hay cambios en heladas, altas y bajas temperaturas, temporalidad de la precipitación y otros eventos extremos, que probablemente tendrán ramificaciones en la estructura y función del ecosistema.

La cantidad de ganado ha disminuido significativamente en el último siglo, a un 20% del ganado que había en la región a principios de 1900. Muchos sistemas han cambiado en los últimos 100 años en términos de herbívoros grandes, pero no existía ganado antes de la colonización. Los efectos negativos del ganado en la productividad del sitio pueden persistir por varias décadas.

El aumento en la abundancia de especies de pasto no nativas representa otro cambio biológico en estos sistemas. Estas nuevas especies han creado sistemas diferentes de los que existían antes de la colonización, y de los que se estudiaron desde la década de los 50 hasta mediados de los 70.

Los cambios en perspectiva son quizá más importantes que los cambios en las condiciones ambientales. La creación de la Sociedad para la Biología de Conservación en los Estados Unidos es evidencia de que nuestros objetivos van más allá de los usos de consumo. Como sociedad, nos interesa la diversidad biológica.

Estos objetivos no incluyen la recreación de condiciones históricas, porque existe muy poca información de las mismas, y porque los sistemas han cambiado con tal profundidad que resultaría imposible reproducir las condiciones anteriores a la colonización. Es necesario que los objetivos de enfoque puedan evaluarse, medirse y repetirse con el tiempo. Esto se aplica a la reintroducción de fuego en estos sistemas, porque el objetivo debe ser claro antes de aplicar el fuego, considerando efectos, temporada y frecuencia.

Es especialmente importante considerar la temporalidad. En la actualidad se usa el fuego en períodos de fácil control. En los pastizales del sudoeste, sucede en marzo y abril, lo que no concuerda con los regímenes de fuego históricos. La mayoría de los incendios en esta región ocurrían a finales de junio y principios de julio, al inicio del monzón sudoccidental. Desconocemos las implicaciones de la aplicación de incendios primaverales en especies que evolucionaron con incendios periódicos en verano.

Finalmente, está claro que debemos poner mayor énfasis en los esfuerzos de monitoreo. El “manejo adaptativo” se ha convertido en el credo de las agencias de manejo de recursos en los Estados Unidos, pero no podemos adaptar el manejo sin la información derivada del monitoreo.

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