FIRE IN RANGELANDS AND ITS ROLE IN MANAGEMENT

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Contents

Summary

Fire is a prevalent feature of most rangelands, whereas not all fire-prone ecosystems are rangelands. The major rangeland ecosystems at a global scale (savanna, grasslands, steppe and grassy woodlands) generally occur in regions of intermediate rainfall, are dominated by grasses and experience regular fire (annually to one every few years). In broad transitional zones with both drier and wetter regions, long-term rainfall deviations are largely responsible for fire in vegetation which otherwise doesn't carry fire. Consequently fire is relatively infrequent in these transitional zones. Within landscapes, fire tends to favor areas having intermediate level of resources, and sharp boundaries between more open, grassy, fire-prone vegetation and fire-sensitive forests/woodlands are relatively common. Fire has been part of savanna and most other grass-dominated ecosystems for millennia, and has been a formidable force in shaping their structure, resilience and biotic composition. Although these forces have been operating long

before humans, increased fire activity associated with human culture is likely to have accelerated and expanded the shift from fire-sensitive to fire-adapted biota in many landscapes. Consequently much of world's savanna, as well as significant areas of other grass-dominated rangelands, rely on regular fire to maintain open structure and grass dominance, and indeed experience increased woody plant cover with fire exclusion. Some rangeland ecosystems have become dominated by trees and shrubs to such a degree that grass cover is suppressed and fire is difficult to re-introduce (an irreversible state transition in ecological terminology). Elsewhere, fire exclusion results in fewer, but more intense and widespread fires, which cause damage to more fire sensitive elements of the biota, particularly where these large fires cross grassland-forest edges. Changes in vegetation due to altered fire regimes is one of the major threats to rangeland productivity, ecosystem health and conservation value. Fire management in rangelands is often based on re-introducing past fire regimes, with patch mosaic burning a commonly recommended practice as it is believed to mimic past burning practices of indigenous peoples. Very few studies have investigated the interactive effects of fire and burning of rangelands, surprising given they coincide over vast areas of the Globe. Post-fire regeneration is often more palatable and nutritious than long unburnt vegetation and, consequently, will attract grazing animals from the surrounding lands. Although such post-fire grazing can be damaging in some ecosystems, it will effectively control fuel levels and, in turn, impart a period of fire protection in these burnt patches. After some years, less palatable or desirable species will begin to dominate the patch and grazers will tend to move on, especially to more recent burnt patches, if present, thereby enabling their recovery. This sequence of fire-grazing-recovery can be repeated in patches across the landscape to enhance overall heterogeneity and biodiversity at this scale. Re-introducing native grazers (or suitable analogues) and/or patch burning has been recommended in areas where such a shifting patch dynamic has been lost. The reduction in fuel by grazers generally results in fewer and milder fires which can lead to increase in woody plant cover. In contrast, browsers, herbivores which feed directly on shrubs and trees, will tend to decrease woody cover, directly through consumption and damage, and indirectly through encouraging more grass fuels and, thereby, intense fires. Although the use of fire as a management tool in rangelands is commonplace, objectives of burning vary and may include: fuel and wildfire threat reduction; stimulation of green 'pick' and improved productivity; woody weed control; carbon sequestration; and conservation and protection of biota and other assets.

1. Introduction

Fire is a common and regular cause of disturbance and driver of change in many biomes and ecosystems across the Globe, from boreal forests to tropical grasslands. It has an important ecological role in such ecosystems, and influences species composition, vegetation structure and dynamics, habitat values and ecosystem functioning, as well as being potentially both beneficial and damaging to people and property. It is vitally important that fire in ecosystems is managed to avoid detrimental impacts while optimizing benefits to humans.

The vast majority of rangelands experience fire to various degrees; for some, fire is a recurrent and highly influential factor. The effects of fire on rangelands, from the perspectives of ecology, culture and livestock production, therefore need to be understood if it is to be appropriately managed. This chapter will cover the ecological foundations of fire in rangelands, and their implications for fire management and planning. As rangelands by definition are uncultivated land able to sustain herbivore populations, either for human consumption or for conservation, a particular focus of the chapter will be on interactions between grazing and fire. Global, regional and landscape patterns of fire and grazing will be explored to determine where, when and how these factors may interact, and management implications of such relationships will be investigated.

2. Global Patterns – Which Rangelands Burn?

Although the majority of the Globe's biomes and major ecosystems experience fire, some never do, and others only in exceptional circumstances. The critical factors determining whether or not a fire will carry in a particular ecosystem are well understood. Firstly, temperature, rainfall and soil fertility must be sufficient to allow an adequate level of primary production, while herbivory and litter decomposition must be low enough to permit biomass (including dead plant material) to accumulate. Next, this biomass should, at times, 'dry off' and become ignitable and thereby contribute to fuel available for fire. Therefore climates fluctuating seasonally or over the longer term tend to be more fire prone. Lastly, certain spatial arrangements of fuel, plants or vegetation, as well as secondary compounds on or within plants (oils, resins etc), can increase flammability and facilitate the passage of fire. These factors together explain why fire does not usually occur in consistently cold climates (e.g. much of the tundra) or in true deserts (where annual precipitation is less than 100 mm) as the quantity of fuel is low and it is sparsely distributed.

Also, fire is not known or very rare in tropical rainforests and cool temperate forests/woodlands, and in other ecosystems with high and relatively consistent rainfall patterns, where litter and biomass mostly remain moist. Tropical rainforests are also noted for high rates of litter decomposition, which imply that there is little fuel accumulation. Humans have modified the structure of these dense, wet forests (by logging, clearing, road construction, etc.), which has resulted in exposure of ground fuels, as well as more plant debris on the ground, so that the fire risk in these vegetation types has dramatically increased. Consequently, large fires in rainforests are now more commonplace.

To clarify the scope of this review, it is important to define which of these fire-susceptible ecosystems are rangelands. Or, put another way, which types of rangeland experience fire, and where are they found across the Globe? Rangelands as defined above potentially cover a wide range of biomes and major vegetation types ranging from deserts to forests on the one hand and to tundra on the other; this suggests, superficially at least, considerable overlap between fire-prone ecosystems and rangelands. However, rangelands require a preponderance of palatable species. Therefore, ecosystems dominated by plants with toxic, small, sharp and/or sclerophyllous leaves, or other deterrent features (e.g. thorns), are not normally considered rangelands since they lack available fodder, even though such vegetation may readily experience fires; in fact, these same plant attributes also tend to promote fire.

Denser forests in more mesic climates are not usually considered rangelands, since the leaves are typically outside the reach of ground-dwelling herbivores. Forests and woodlands which are more open and have a pronounced understory are fire-prone, and often have palatable herbs and shrubs, although on infertile soils the understory is more likely to be dominated by unpalatable sclerophyllous species with little nutritional value. Open woodland, savanna and grassland ecosystems are globally the main rangelands ecosystems, although, again, poor soil fertility may diminish the forage value of the vegetation. For instance, infertile grasslands and savanna of southern Africa do not support large number of grazing animals.

Similarly, many of the hummock grasses which dominate large expanses of the northern arid zone of Australia are unpalatable as a result of their sharp needles and toughness (colloquially they are known as 'hard spinifex' species); as a result of which they are not grazed by either introduced or native herbivores (unless recently burned, see Section 4). Heathlands and shrublands of Mediterranean climates, which develop on nutrient-poor soils and experience fire regularly, are also typically dominated by non-palatable species. On the other hand, there are large areas of drylands and near coastal areas with saline and/or alkaline soils dominated by succulent halophytes, which may constitute excellent fodder for grazing animals, but do not tend to experience fire.

Therefore, at a global scale, the biomes covering large areas which experience both regular fire and grazing are: 1) open forest, woodland and savanna (but only on relatively fertile soils); and 2) steppe and other grasslands (both temperate and tropical). These biomes cover some 20% of the Earth's land surface (Figure 1) and will form the main focus of this review. Generally such vegetation occurs in medium-rainfall zones (~200-800 mm annual precipitation), with more arid and mesic extremes generally excluded from this review for reasons outlined above. However, broad transitional zones between climates are also of relevance as seasonal and inter-annual rainfall variability plays an important role in determining fire occurrence in them. For instance, in the transitional zone between arid/desert climates and semi-arid shrubland (around 100 to 300 mm annual precipitation), fire will tend to occur relatively rarely following periods of sustained high rainfall which have led to the accumulation of more fuel than usual, and over a longer period.

Similarly, in the transition zone to more mesic climates (say 700-1200 mm annual precipitation), prolonged drought may dry normally moist ground fuel out, and promote fire. The effect of current anthropogenic climate change on fuel characteristics, fire weather and, consequently, fire behavior is likely to be most acute in these transitional climatic zones. More erratic rainfall patterns would be expected to increase the incidence of fire in these zones.

Such generalizations do not exclude the possibility that fire and grazing may occur together under certain conditions and circumstances in other biomes and ecosystems. Tundra, for example, is typically inflammable because of the low fuel mass and sustained high moisture levels, both of the plants and of the underlying peat. But, where grasses are a major component, tundra vegetation may carry fire in summer; and, following prolonged drought periods, peat layers may become ignitable and carry fire, often with dramatic impacts. Boreal forests may experience fire, particularly where dominated by conifers, and indeed regular anthropogenic fire has been used historically to reduce tree cover and establish grazing meadows for herbivores such as deer, moose, etc. Typically boreal landscapes are a complex mosaic of grasslands, low shrublands, wetlands and forest vegetation, a pattern partly attributable to fire. The boreal forests themselves can also support grazing animals through new (palatable) leaves, lichens, berries and so on.

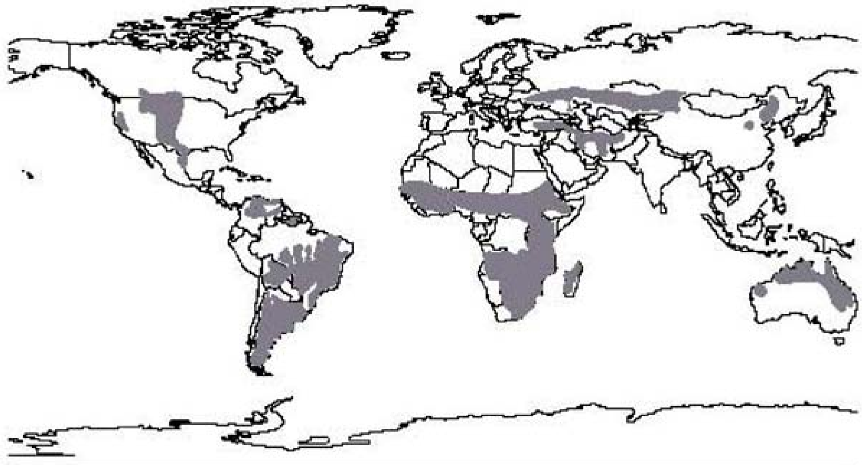

Figure 1. Approximate global distribution of rangelands where fire is generally common and widespread (corresponds to temperate grassland, steppe, open woodland and savannah biomes).

Alpine and sub-alpine areas often support grazing animals, thanks to the preponderance of grasses, moss-beds and other palatable plants where and when the snow has melted, particularly in more open vegetation above the tree line. Such vegetation constitutes the major area of rangelands in temperate mountainous regions and in countries such as New Zealand, Switzerland and Japan. Alpine vegetation also usually experiences fire on a regular or semi-regular basis. Shrubland ecosystems of Mediterranean type in Europe and the Middle East have long supported goats and other herbivores, although this is not the case in similar shrublands in many other parts of the world where humans have not altered them to the same degree by burning, cutting and grazing to reduce shrub cover and promote grasses. Thus, areas subject both to grazing and to fire cannot be simply delineated from climate – vegetation overlays, even at a broad scale.

One of the main global anomalies is the uneven role of fire in shaping global vegetation patterns. Modeling vegetation cover and type at a global scale based on climatic factors alone have shown that much of tropical C_4 grassland and savanna, especially in Africa and South America, should be forest. Many of these tropical savannas occur in areas with relatively high rainfall (1000-2000 mm; e.g. northern Australia, Bolivia, Brazilian *cerrado*, central Africa) and it is likely that this is because regular fire has long suppressed tree and shrub regeneration, while promoting grass cover. This modeling supports long-term fire exclusion studies in such mesic savanna, indicating a gradual return to tree cover when areas have not been burnt for a considerable period, and suggesting that these systems are generally created and maintained by fire.

3. Landscape- Scale Patterns of Rangeland Fire

The broad patterns and causal agents generally seen at a global scale, as described in the preceding section, are repeated to a certain degree at the landscape scale. This is illustrated by the example of catenae in semi-arid environments, running from hill top to valley floor. In lower parts of landscape which receive extra water through run-off from the slopes above, and where accumulation of alluvium and nutrients has occurred, these extra resources tend to promote denser vegetation which is less likely to carry a fire. Upslope rocky areas, as well as other areas of shallow, stripped or infertile soils, would support lower biomass and a more discontinuous supply of fuel, with consequent lower fire susceptibility. Often fire-sensitive species persist in these parts of the landscape, which are sometimes referred to as fire refuge zones. Generally fire is most prevalent in the middle section of the catena; provided the soils here are not deficient in nutrients or otherwise limiting for growth, these parts of the landscape are also likely to support grasses and therefore herbivores. Therefore, redistribution of resources across the landscape, by the actions of water, wind and gravity, has a profound, albeit indirect, influence on fire susceptibility and behavior.

Following these considerations, one may distinguish between 'fire-prone' vegetation on the one hand, which carries fire easily, but readily recovers from it, and 'fire-sensitive' vegetation, where fire is less common but much more destructive. Transitional zones between them are of special interest since fire and grazing are particularly influential in the vegetation dynamics thereof (see Section 8), and have received much research attention. In many places, a relatively distinct boundary is evident between forest (or denser and more fire-sensitive vegetation) and grassland-savanna (or other more open, fire-prone vegetation) which experiences regular fire. Such sharp boundaries, or ecotones, are commonly the product of fires, the position of the boundary tending to reflect the limit of the most recent 'hot' fire(s) burning from the savanna into the forest/woodland.

Such boundaries are potentially dynamic. Tree invasion from the edge occurs if the savanna-grassland is unburnt for some time; on the other hand, fire entering the forest will tend to result in a contraction of the boundary into the forest. A common feature of these transitional zones is that islands of woody vegetation persist on the grassland/savanna side of the transition, which is often interpreted as evidence of recent retreat of the boundary.

Disjunctions in landform and soil may also play a role in forming such boundaries, and their influence is generally under-appreciated. The transitional zone across which such boundaries can shift will therefore be relatively narrow if there are edaphic limits to species expansion. Furthermore, a number of processes operate to make edges more stable over time, including soil, hydrological, microclimatic and vegetation differentiation across the edge, and inhibition of tree re-establishment by competition and exposure in the more open vegetation. For example, it has been reported in semi-arid lands that vegetation of the woodland edge becomes thicker over time in response to surface water runoff from upslope savanna and subsequent trapping and accumulation of alluvium and nutrients by trees at the edge. This thickening would tend to render edges more resistant to future fires. As an example of competitive effects, in central Tasmania dense grass swards were considered to be the main reason preventing tree spread from eucalypt forest into adjoining grassland. In central and north-west Australia, in more hilly terrain, sharp boundaries between mulga (vegetation dominated by fire-sensitive *Acacia aneura* in valleys and fire-free niches) and hummock grassland (dominated by fire-prone *Triodia* on slopes) are known to have shifted at some localities, although the vast majority seem to have remained stable. In southern Brazil, mixed *Araucaria*—broad-leaf forest has shifted upslope into adjoining grassland (known locally as *campos*) at some long-unburned sites, but not others. It is has been hypothesized this is because moisture limitations at the latter sites discourage tree establishment. Thickets of pioneer rainforest species have been known to expand into savanna in West Africa in the absence of fire; however, their rate of spread is slow, new trees mostly establishing only at the forest edge. Again some factor seems to be inhibiting tree spread into grass-dominated area.

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Biographical Sketch

Eddie van Etten completed his PhD at Curtin University in Perth, Western Australia in 2000. His PhD research was on the vegetation patterns and dynamics of the Hamersley Ranges, spectacular semi-arid and arid uplands of north-west Australia. Eddie has been employed as a Lecturer and, later, Senior Lecturer in Environmental Management at Edith Cowan University in Perth since 1991, where he teaches ecosystem management, forest management and ecological restoration. Research interests have broadly covered vegetation ecology and management of forests, woodlands, shrublands and hummock grasslands of Western Australia, particularly studies of the impacts of fire, grazing and timber harvesting in such ecosystems. Fire studies in rangelands have included the role of fire in shaping landscape vegetation patterns, particularly woodland-grassland boundaries, and the fuel characteristics of woodlands invaded by exotic grasses. He also has interests in restoring landscapes disturbed by mining and other human activities. He has written or co-written 12 peer-reviewed papers, 20 other research papers and some 21 research reports on these topics.