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Tamm Review: Shifting global fire regimes: Lessons from reburns and research needs

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ABSTRACT

Across the globe, rising temperatures and altered precipitation patterns have caused persistent regional droughts, lengthened fire seasons, and increased the number of weather-driven extreme fire events. Because wildfires currently impact an increasing proportion of the total area burned, land managers need to better understand reburns – in which previously burned areas can modify the patterns and severity of subsequent fires. For example, knowing how long past fire boundaries can function as barriers to fire spread may empower decision-makers to manage some wildfires as large-scale fuel treatments, or alternatively, determine where prescribed burning or strategic wildfire management are required. Additionally, a clear understanding of how prior burn mosaics influence future fire spread and burn severity is critical knowledge for landscape and fire-dependent wildlife habitat planning under a rapidly changing climate. Here, we review published studies on reburns in fire-adapted ecosystems of the world, including temperate forests of North America, semi-arid forests and rangelands, tropical and subtropical forests, grasslands and savannas, and Mediterranean ecosystems. To date, research on reburns is unevenly distributed across the world with a relative abundance of literature in Australia, Europe and North America and a scarcity of studies in Africa, Asia and South America. This review highlights the complex role of repeated fires in modifying vegetation and fuels, and patterns of subsequent wildfires. In fire-prone ecosystems, the return of fire is inevitable, and legacies of past fires, or their absence, often dictate the characteristics of subsequent fires.

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1. Introduction

Over recent decades, many parts of the world have witnessed a dramatic rise in the incidence and area burned by wildfires (Westerling et al., 2006; Flannigan et al., 2009). Globally, rising temperatures are extending droughts and increasing the number of weather-driven fire events and lengthening fire seasons (Jolly et al., 2015). Large increases in the annual area burned have been documented for the western United States (Littell et al., 2009; Miller et al., 2012; Dennison et al., 2014), bush regions and eucalypt forests of Australia (Williams et al., 2009), boreal forests (Kasischke and Turetsky, 2006), subtropical pine forests (Mitchell et al., 2014), and tropical rainforests and savannas (Brando et al., 2014). Because wildfires generally impact a much greater proportion of the area managed than prescribed burns and other fuel reduction treatments, land managers need to better understand reburns – prior wildfires, which can modify the patterns and severity of subsequent fires. For example, knowing how long past fire boundaries can function as barriers to future fire spread can enable decision-makers to manage more wildfires as large-scale fuel treatments, or alternatively, determine when and where fire suppression or prescribed burning may be strategically needed. An understanding of how past burn mosaics can regulate future fire spread and burn severity is also critical for landscape and fire-dependent habitat planning, especially in the context of a changing climate. Here, we review studies of reburns in fire-adapted ecosystems that share a legacy of 20th-century fire exclusion (see Box 1).

Box 1 High severity fires can accelerate vegetation lifeform changes.

Given 21st-century climate change scenarios, widespread non-native species invasions, and past fire exclusion across most global wildfire ecosystems, this is a challenging time for fire managers. Many historically fire-prone ecosystems have experienced a chronic fire deficit and now exhibit highly altered fire regimes. In previously fuel-limited systems with frequent fire returns, fires now burn more intensely and contagiously over broader areas. For example, in ponderosa pine (*Pinus ponderosa*) dominated forests of the western United States (US), frequent surface fires historically maintained light and patchy surface fuels under low- or mixed-severity fire regimes (Agee and Skinner, 2005; Hessburg and Agee, 2003). After nearly a century of fire exclusion, surface and canopy fuels have accumulated, as has horizontal and vertical continuity of fuels at patch to regional landscape scales – predisposing some dry pine and mixed-conifer forests to more intense fire behavior and severe fire effects (Hessburg and Agee, 2003; Hessburg et al., 2005; Malleck et al., 2013; Stephens et al., 2012). Similar trajectories of increased forest cover, density, layering, fuel accumulation, and susceptibility to large, high-intensity fires have been documented in African dryland savannas (Bond and Archibald, 2003; Staver et al., 2011), South American cerrado (Geiger et al., 2011; Pivello, 2011), subtropical pine forests and savannas (Brockway et al., 2005; Stambaugh et al., 2011), and Australian dryland Eucalypt forests and woodlands (Burrows and McCaw, 2013). In a time of climate change, high-severity fires can accelerate vegetation lifeform changes via their frequency and size (Odion et al., 2010).

Table 1
Summary of major vegetation types and fire management issues.

Biome	Vegetation type/region	Fire and fuels management issues
Semi-arid forest and rangelands (North America)	Mixed conifer forests and savannas	Fire exclusion and fuel accumulation; altered fire regimes, expanding wildland urban interface
	Sagebrush and other shrub steppe ecosystems	Invasive grass species and altered fire regimes
Tropical ecosystems	African grasslands and savannas	Maintenance of grasslands and savannas
	Amazon rainforest and Cerrado	Forest clearing and escaped wildfires in rainforests; fire exclusion and fuel accumulation in the Cerrado.
	Australian eucalypt forests and savannas	Altered fire regimes; invasive species
	Subtropical forests, southeastern United States	Fire exclusion and fuel accumulation; altered fire regimes
Mediterranean ecosystems	European Mediterranean	Decrease in rural burning practices and need for prescribed burning programs

Managers of fire-excluded ecosystems face a backlog of work to restore fire-regimes and promote resilience to future fires (Varner et al., 2005; Moritz et al., 2014; Hessburg et al., 2015). In many regions, only a small fraction of fire-dependent landscapes are treated each year (Quinn-Davidson and Varner, 2012; Ryan et al., 2013; Fernandes et al., 2013; McCaw, 2013). Simultaneously, the area burned by wildfires has increased sharply in recent decades, often with different ecological outcomes than historical fire regimes or prescribed burns (Russell-Smith et al., 2007; Cansler and McKenzie, 2014). Mechanical treatments to reduce existing surface and canopy fuels may be necessary in some landscapes before fire can be reintroduced and mitigate the risk of very large, high-severity fires (Stephens et al., 2012; Mitchell et al., 2014; Hessburg et al., 2016).

Depending on the severity and extent of prior fire events, past fires can act as temporary barriers to future fire spread (Collins et al., 2009; Moritz et al., 2011; Teske et al., 2012; Parks et al., 2015a). Because fuels are consumed and reduced for a time after fires, there is less available fuel to burn in subsequent wildfires. After vegetation recovers, previously burned landscapes can be readily reburned in subsequent fire events (Parks et al., 2015b).

In many regions of the world, wildfires are influencing a much greater proportion of the area than prescribed fire and other fuel reduction treatments, and land managers need a better understanding of reburns to inform wildland fire management. For example, knowing how long past fire boundaries remain barriers to fire spread may empower decision-makers to manage some wildfire ignitions as large-scale fuel treatments, or alternatively, determine when and where strategic wildfire management or prescribed burning are required (Agee and Skinner, 2005; Finney et al., 2007; Reinhardt et al., 2008). An understanding of how burn mosaics can regulate future fire spread and burn severity is also critical for landscape planning. Specifically, it is important to anticipate where past fires may or may not act as barriers to subsequent fires (e.g., Price et al., 2015), and where vegetation and fuels management are necessary to restore fire regimes that perpetuate fire-adapted vegetation and habitats. There also is a growing concern that large, high-severity fire events can synchronize changes in lifeform dominance across large areas (Lonsdale, 1994; Hessburg et al., 2007, 2016; LaRosa et al., 2007; Meyn et al., 2007; Moreira