POLICY PERSPECTIVE

Effects of logging on fire regimes in moist forests

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Abstract

Does logging affect the fire proneness of forests? This question often arises after major wildfires, but data suggest that answers differ substantially among different types of forest. Logging can alter key attributes of forests by changing microclimates, stand structure and species composition, fuel characteristics, the prevalence of ignition points, and patterns of landscape cover. These changes may make some kinds of forests more prone to increased probability of ignition and increased fire severity. Such forests include tropical rainforests where fire was previously extremely rare or absent and other moist forests where natural fire regimes tend toward low frequency, stand replacing events. Relationships between logging and fire regimes are contingent on forest practices, the kind of forest under consideration, and the natural fire regime characteristic of that forest. Such relationships will influence both the threat of fire to human life and infrastructure and biodiversity conservation. We therefore argue that conservation scientists must engage in debates about fire and logging to provide an environmental context to guide considered actions.

Introduction

Does logging reduce the fire proneness of forests? This question is often posed after major wildfires, especially those marked by substantial loss of human life or infrastructure, such as occurred in February 2009 in south eastern Australia, the worst fires in Australia's history with the loss of 173 lives and more than 3000 homes. In the wake of fires such as these, calls for forests to be logged to prevent major wildfires have been made by senior public officials (Tuckey 2001) and by a key lobby group (National Association of Forest Industries 2009a,b,c). Similar arguments have also characterized fire and forest management debates in western North America (DellaSala *et al.* 2004; Odion *et al.* 2004). For example, Aber *et al.* (2000, p. 12) noted that "conversion of old growth forests in the Pacific Northwest [of the USA] has sometimes been justified on grounds that it reduced the potential for catastrophic fire." They further stated that perceptions that managed (logged) landscapes are less susceptible to wildfire than unmanaged ones are "an article of faith." Indeed, the opposite may be the case in some forests as we show in this article through a brief examination of relationships between logging and several aspects of fire regimes. This is an important issue because it could have profound consequences for how forests are managed, including some that are currently reserved. As a consequence, the issue has been raised in post fire commissions of inquiry in places like Australia and Canada. Potential changes in natural fire regimes underpinned by rapid climate change (Cary 2002; Lenihan *et al.* 2003; Westerling *et al.* 2006; Flannigan *et al.* 2008; Cochrane & Barber 2009) and hence interactions between management practices and altered climate further underscore the importance of this issue.

Our focus is on relationships between industrial logging practices in native forests (i.e., not plantations) and alterations to natural fire regimes (*sensu* Gill 1975) that might include (among others) changed susceptibility to ignition, altered fire severity, altered fuel loads and fuel condition, and changed fire frequency. Altered fire regimes can have significant negative effects on biodiversity in moist forests (Holdsworth & Uhl 1997; Brown *et al.* 2004; Noss *et al.* 2006b; Lindenmayer *et al.* 2008), especially those forest types where wildfires are extremely rare or even a novel kind of major natural disturbance (e.g., some kinds of tropical rainforest, Uhl & Kauffman 1990; Cochrane & Barber 2009).

We consider industrial logging and forest management to include the array of activities associated with the harvesting of timber and pulpwood from a forest including the construction of road networks, the cutting of trees, and postharvesting stand regeneration. We do not discuss in detail the broader issues of forest fire management as this is a vast literature. Similarly, we do not examine the already extensively explored topic of promoting greater congruence between natural disturbance regimes and human disturbance regimes, notably logging (Hunter 2007). However, we note that natural fire regimes cannot simply be replaced with regulated disturbance by logging (Hunter 2007). This is because, in part, many elements of forest flora and fauna depend on particular fire return intervals and associated habitat features (Saint-Germain *et al.* 2004). Logging operations also do not provide the diversity of habitats and micro site conditions found after wildfires (Haeussler & Kneeshaw 2003; Lindenmayer *et al.* 2008). We also of course recognize, but do not discuss, an extreme response to managing forest fires, which is to remove forests and the fuel they support, altogether. Forests and their susceptibility to fire are characterized by a continuum of precipitation and humidity ranging from relatively moist to relatively dry; we focus primarily on fire in relatively moist forests where fires naturally occur at a lower frequency relative to dry forests. Relationships between some kinds of logging practices (e.g., thinning operations) and fire regimes may differ between moist forests and dry forests (e.g., Covington 2003; Noss *et al.* 2006a) and we briefly discuss this issue toward the end of this article.

This article is based on our past experience in working in different forest types coupled with a recent (3 August 2009) search of the fire, fire management, forest management, and conservation biology literature. Although our search was extensive and encompassed more than 650 articles, we fully acknowledge that it was not comprehensive and we only touch on key points rather than examine each in detail. However, to the best of our collective knowledge, there has been to date no detailed published review of the how industrial logging policies and practices can alter fire regimes.

Logging and fire regimes

Logging can change forests in at least five interrelated ways that could influence wildfire frequency, extent and/or severity. These include changing: (1) microclimates, (2) stand structure and species composition, (3) fuel characteristics, (4) the prevalence of ignition points, and (5) patterns of landscape cover (Figure 1)

Changes in microclimate

The removal of trees by logging creates canopy openings and this in turn alters microclimatic conditions, especially increased drying of understorey vegetation and the forest floor (Ray *et al.* 2005; Miller *et al.* 2007). As with the influence of forest edges (Harper *et al.* 2005), microclimate effects (including fuel drying) associated with forest harvesting can be expected to be greatest where the unmodified forest is moist. Work in tropical rainforests suggests that when microclimatic conditions are altered by selective logging, the number of dry days needed to make a forest combustible is reduced (Kauffman & Uhl 1991; Holdsworth & Uhl 1997; Malhi *et al.* 2009). In one study, uncut native forest would generally not burn after >30 rainless days but selectively logged forest would burn after just 6–8 days without precipitation (Uhl & Kauffman 1990). Similarly, Nepstad *et al.* (1999) estimated that logging increased the flammability of tropical rainforest by 14–50%.

Changes in stand structure and plant species composition

Many studies document how logging alters the structure and species composition of forest (reviewed by Hunter 1999; Lindenmayer & Franklin 2002). Such changes not only alter microclimatic conditions as described above, but also can change stocking densities and patterns of trees, inter crown spacing, and other forest attributes such as plant species composition. These changes can, in turn, influence fire regimes (e.g., Ray *et al.* 2005). For example, logging in some moist forests in south eastern Australia has shifted the vegetation composition toward one more characteristic of drier forests that tend to be more fire prone (Mueck & Peacock 1992). Research in western North America indicates that logging related alterations in stand structure can increase both the risk of occurrence and severity of subsequent wildfires through changes in fuel types and conditions (Thompson *et al.* 2007). Similarly, in Asian rainforests, post fire salvage logging changed the vegetation composition towards more fire-prone grassland taxa, which in turn damaged fire sensitive remnant rainforest stands (van Nieuwstadt *et al.* 2001).

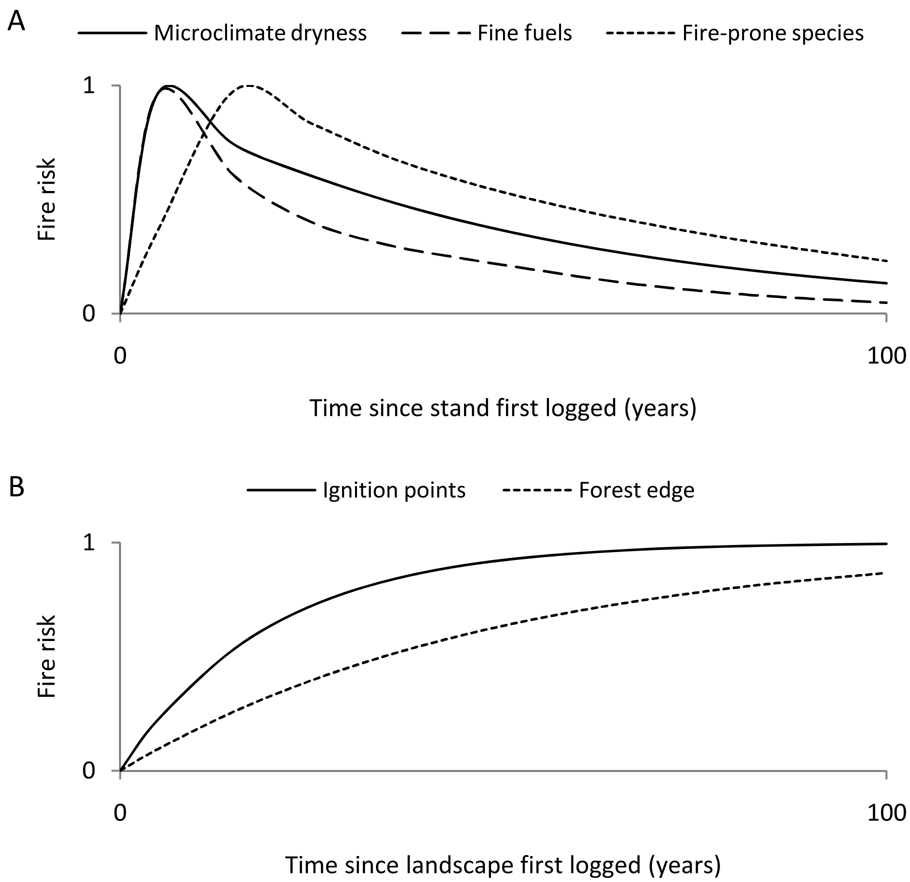

Figure 1 Hypothesized changes to variables that affect: (A) fire risk at the scale of a single stand (i.e., microclimatic dryness, fine fuels, the prevalence of fire-prone species) and (B) fire risk at the scale of a landscape (i.e., ignition points, amount of forest edge) in which the same number of stands are logged per annum. The y-axis is relative abundance with zero equal to pre-logging levels. The x-axis is time since first logging, that is, it is assumed that no logging has occurred at time zero.

Changes in fuel characteristics

Logging can alter fire regimes by changing the amount, type, and moisture content of fuels (Perry 1994; Weatherspoon & Skinner 1995; Thompson *et al.* 2007; Krawchuk & Cumming 2009). As an example, work in western North America has highlighted how post fire salvage logging created additional fine fuels and led to elevated short-term risks of subsequent fires (Donato *et al.* 2006). Whelan (1995) noted that clearfelling of moist forests in southern Australia led to the development of dense stands of regrowth saplings that created more available fuel than if the forest was not clearfelled. Large quantities of logging slash created by harvesting operations can sustain fires for longer than fuels in unlogged forest and also harbor fires when conditions are not suitable to facilitate flaming combustion or the spread of fire (Cochrane & Schulze 1999). Holdsworth & Uhl (1997) quantified increased fuel drying in selectively logged Amazonian rainforest, and these effects declined with increasing time since logging as openings regenerated.

Change in ignition points

The road networks required for logging operations create an increased number of ignition points for wildfires. A substantial increase in ignitions and fire frequency in Russian boreal forests (Achard *et al.* 2006) has been attributed, in part, to roads built for logging and mining (Dienes 2004; Bradshaw *et al.* 2009). Even natural lightning initiated ignition points may be influenced by logging. In Canadian mixedwood boreal forests, fire initiation following lightning strikes is more likely to occur in harvested areas because of increased fine fuels resulting from logging slash and this effect can remain for 10–30 years following logging (Krawchuk & Cumming 2009).

Change in the spatial pattern of stands

Logging operations change natural patterns of spatial juxtaposition of different kinds of forests stands (i.e., patterns of landscape heterogeneity) (Franklin & Forman 1987). This, in turn, can change spatial contagion in the spread of wildfire through landscapes (Whelan 1995; Bradshaw *et al.* 2009) with some areas traditionally characterized by an absence of fire becoming more susceptible to being burned by fires that spread from adjacent, more flammable, logged areas (Holdsworth & Uhl 1997; Perry 1998; Nepstad *et al.* 1999; Malhi *et al.* 2009). Similarly, forest edges created by logging and by logging roads can become sites for fire incursions into adjacent forests (Cochrane & Laurance 2002). Empirical analysis in Canadian forests (Arienti *et al.* 2006) has failed to support the presumed efficacy of road networks in facilitating wildfire containment and prompt fire suppression.

An alternative perspective from dry forests

Relationships between logging and the frequency, extent and severity in some kinds of dry forests can differ from moist forests (Noss *et al.* 2006b). These include forests where prolonged fire suppression activities have altered natural fire regimes by increasing fuel loads and thereby elevated the risk of uncharacteristic high severity wildfires (Harrod *et al.* 2009). Examples include ponderosa pine (*Pinus ponderosa*) forests of the south western United States (Covington 2003; Noss *et al.* 2006a), dry east side coniferous forests of the Pacific Northwest (Spies *et al.* 2006; Harrod *et al.* 2009) and the pine forests of the south eastern United States (Phillips & Waldrop 2008). In these forests, tree removal can be employed as an appropriate restoration technique if thinning is aimed at removing unnaturally high fuel loads, thereby reducing the likelihood of inappropriate high severity wildfires (Noss *et al.* 2006b; Spies *et al.* 2006). Nevertheless, if thinnings are left on site rather than taken out of the forest for disposal, these operations too can elevate the risk of unplanned ignitions (Schroeder *et al.* 2006). Carefully prescribed tree removals also can be the first step in recreating a modern (although somewhat crude) analogue of past fire regimes (Covington 2003; Noss *et al.* 2006a). In dry forests that do not require restoration, the key questions are likely to be: how does logging affect the amount and condition of fuel and the likelihood of ignition events?

Concluding remarks and policy implications

The likelihood of human caused ignitions and the accumulation of dry fuels are the basis for longstanding forestry practices such as "closing" forests to industrial operations during extreme fire weather, and widespread prescriptions for slash disposal, respectively. It has been argued by some that, "industrial logging was a source of almost unprecedented holocausts…" (Pyne 1982, p. 182) in the past. Contrary to claims by some commentators (e.g., National Association of Forest Industries 2009a,b,c), industrial logging is likely to make some kinds of forests more, not less, prone to an increased probability of ignition (Krawchuk & Cumming 2009) and increased fire severity and/or fire frequency (Uhl & Kauffman 1990; Thompson *et al.* 2007; Bradshaw *et al.* 2009; Malhi *et al.* 2009). Such places include tropical rainforests where fire was previously extremely rare or absent (Uhl & Kauffman 1990; Barlow & Peres 2004; Malhi *et al.* 2009), and other moist forests where natural fire regimes tend toward low frequency, stand replacing events (Whelan 1995; Odion *et al.* 2004; Bradshaw *et al.* 2009). These altered fire regimes can, in turn, have significant negative effects on a range of elements of forest biodiversity (Uhl & Kauffman 1990; Lindenmayer & Franklin 2002; Barlow & Peres 2004; Cochrane & Barber 2009).

Relationships between industrial forest management and fire regimes are contingent on the kind of forest under consideration and the natural fire regime characteristic of that forest (Brown *et al.* 2004; Noss *et al.* 2006b). Despite the importance of understanding such relationships, studies directly examining them are not particularly common in the majority of forest ecosystems (but see Uhl & Kauffman 1990; Odion *et al.* 2004; Thompson *et al.* 2007) and this suggests an important role for additional research in many parts of the world. These investigations could include *post hoc* studies of fire ignition and severity in forests subject to different management regimes (e.g., Weatherspoon & Skinner 1995; Thompson *et al.* 2007; Krawchuk & Cumming 2009). Such additional studies are essential for at least three key reasons. First, relationships between industrial logging and wildfire are likely to be important in many kinds of forests worldwide—as suggested by the examples touched on in this article. Hence, it is critical to identify and then manage the factors that may exacerbate problems associated with altered fire regimes (Malhi *et al.* 2009). Second, climate change is likely to drive substantial changes in fire regimes (Cary 2002; Westerling *et al.* 2006; Flannigan *et al.* 2008; Pittock 2009). If industrial logging changes fire proneness, then interactions between logging and climate change could lead to cumulative negative impacts, including those on biodiversity.

Conversely, recent work in Amazonia suggests that some kinds of forest may have some inherent resilience to climate change through maintaining mesic microclimate conditions if other agents such as logging are left undisturbed (Malhi *et al.* 2009). Third, a better understanding of relationships between logging and wildfire will improve policy making and forest management. For example, in moist forests there may be a case to create buffer areas adjacent to human settlements. In addition, there may be a strong case to exclude logging from those areas where past human disturbances (like timber harvesting) have been limited (Cochrane & Barber 2009). This is because logging induced alterations in landscape cover patterns can take prolonged periods to reverse and hence associated changes in fire susceptibility also may be long lived (Perry 1998). More refined studies of relationships between industrial logging and wildfire also might identify ways to manage post harvesting slash (e.g., prescribed burning, biofuel production) to reduce fire risks (Weatherspoon & Skinner 1995).

Perfunctory responses to natural resource management problems are commonplace after major natural disturbance events that have catastrophic effects on humans and on infrastructure (Lindenmayer *et al.* 2008). Calls to log forests to save them (Tuckey 2001) are overly simplistic. In this case, fire and forest management recipes suitable in one situation (e.g., for restoring the natural fire regime of a dry forest) might be inappropriate (and even counter productive) in another (e.g., a relatively moist forest) (Brown *et al.* 2004). In both situations, management actions will influence the threat of fire to human life and infrastructure and also affect all other aspects of the forest (e.g., biodiversity and the provision of ecosystem services; Barlow & Peres 2004; Phillips & Waldrop 2008). Therefore, conservation scientists must strongly engage with these issues in public fora. They need to argue that environmental context is critically important to guide considered actions.

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