SCIENCE FEATURE

The hidden consequences of fire suppression

By Carol Miller

Abstract

Wilderness managers need a way to quantify and monitor the effects of suppressing lightning-caused wildfires, which can alter natural fire regimes, vegetation, and habitat. Using computerized models of fire spread, weather, and fuels, it is now possible to quantify many of the hidden consequences of fire suppression. Case study watersheds in Yosemite and Sequoia–Kings Canyon National Parks were used to simulate where fires might have spread if they had not been suppressed, and what effects those fires would have had on fuels.

Key words

fire suppression, fire use, simulation modeling

EXCLUDING FIRE CAN HAVE DRAMATIC EFFECTS ON ECO-systems. Decades of fire suppression in national parks and other protected areas have altered natural fire regimes, vegetation, and wildlife habitat (Chang 1996; Keane et al. 2002). Suppressing lightning-ignited wildfires removes one of the most important natural processes from fire-dependent ecosystems, and runs counter to the untrammeled characteristics for which wilderness is to be managed. Many, if not most, lightning-ignited fires are suppressed in wilderness for myriad reasons and yet resource specialists have not had a good way to measure or monitor the effects of these management actions. What if we did not suppress these fires? Where would these fires have spread, and what would the effects have been? Can we quantify the impacts of suppressing these fires?

Recently, we asked these questions for two case study areas in the Sierra Nevada of California, both of which are almost entirely designated wilderness: the 74,057-acre (29,970 ha) South Fork of the Merced River watershed in Yosemite National Park and the 223,573-acre (90,480 ha) Upper Kaweah watershed in Sequoia–Kings Canyon National Parks. Yosemite and Sequoia–Kings Canyon National Parks have been leaders in the restoration of fire as a natural process. By 1970, both parks had instituted a policy whereby lightning-caused fires could be allowed to burn in certain areas. Despite these efforts, the parks continue to struggle with restoring natural fire regimes, and the majority of lightning-caused ignitions are suppressed for myriad biophysical and social reasons. For example, most of the South Fork of the Merced watershed has not burned since before the 1930s. This watershed contains the townsite of Wawona and the Mariposa grove of giant sequoia trees (*Sequoiadendron giganteum*), and fires are typically suppressed, which has led to unnaturally high fuel accumulations. In the Upper Kaweah watershed in Sequoia–Kings Canyon, about half of the lightning-caused ignitions are suppressed. The Upper Kaweah watershed contains most of the park's infrastructure and giant sequoia groves, and has a diversity of boundary interface issues. Because of the watershed's proximity to developed areas and topography that drains into the San Joaquin Valley, smoke and its impacts on air quality are a primary concern.

Models used

To quantify the impacts of suppression in these two study areas, a new retrospective modeling approach was developed (Davis et al. 2010) with an existing computer simulation tool called FARSITE (Fire ARea SImulaTor) (Finney 2004). FARSITE uses spatial information about topography and fuels, along with weather and wind data, to simulate the spread and behavior of wildland fire. FARSITE commonly supports fire incident management by using weather forecasts and projecting potential fire growth into the future (e.g., Finney and Ryan 1995), but in this case it was used to investigate where fires in the *past* might have spread. This retrospective application is particularly appealing because it avoids the uncertainty inherent in weather forecasts. When applied to past events, *actual* weather observations are used when running the model.

FARSITE was employed to simulate the spread and behavior of lightning-caused fires that were suppressed in the two study areas for an 11-year period (1994–2004). Suppressed lightning ignitions that occurred in this period were modeled chronologically, using actual weather conditions. The simulated spatial extent and severity of these modeled fires were used to update fuels data after each simulation year. Burn severity was defined according to the degree of fuel consumption that would be seen from a remotely sensed (aerial) perspective. This definition is compatible with Normalized Burn Ratio techniques of assessing fire severity (Key and Benson 2006; Thode 2005; Miller and Thode 2007) wherein remotely sensed imagery is used to assess the degree of change in vegetation before and after fire. The extent and severity of real fires that occurred during the study period were also included in the analysis, and fuels data were updated accordingly for any real fires that may have burned using burn severity data that were available (Thode 2005).

Park records indicate that 34 lightning ignitions in the South Fork of the Merced watershed and 71 lightning ignitions in the Upper Kaweah watershed were suppressed from 1994 to 2004. However, only ignitions with a significant potential for spread were considered. We omitted those that were detected and recorded in the fire occurrence database but that probably would never have spread from their ignition point because of fuel discontinuities, high fuel moistures, or subsequent weather conditions (e.g., rain). A combination of fire danger and fuel flammability was used to estimate each ignition's potential for spread; those with low potential were assumed to be "non-starters" and were ignored. For those lightning-caused ignitions with the potential for significant spread (10 in the South Fork of the Merced watershed and 32 in the Upper Kaweah watershed), FARSITE was employed to simulate fire spread and behavior. The actual hourly weather and wind observations from the time period during which the fire would have burned were used in the modeling.

The consumption of fuels by fire and the accumulation of fuel from year to year were simulated by way of a newly created dynamic model of fuel succession (Davis et al. 2009). This expert opinion–based fuel succession model was developed as part of the study in collaboration with scientists and managers from the parks and the U.S. Geological Survey (USGS). This deterministic model predicts how fuels can be expected to change over time. Fuels are represented by 1 of 22 fire behavior fuel models (Scott and Burgan 2005) that describe the available (burnable) portions of the vegetation (Scott and Burgan 2005). A fire behavior fuel model describes a fuel type in terms of how fire is expected to behave (Anderson 1982). For example, a conifer forest with a moderate load of dead and down woody fuel on the forest floor, represented as a Timber Litter 3 (TL3) fuel model, would be expected to have very low spread rates and flame lengths, whereas a forest represented by Timber Understory (TU5) with higher loads of surface fuel loads and a shrub understory would be expected to have higher spread rates and flame lengths. In the succession model, transitions from one fuel model to another and the rates of these transitions were based on expert knowledge of how vegetation would be expected to react to fires of low, moderate, and high burn severities and how quickly fuels accumulate in the associated vegetation types. Twenty-two diagrams were created to describe fuel succession for each of the fuel models present in the parks (table 1, fig. 1).

In a novel approach, FARSITE and the fuel succession model were used in tandem each year from 1994 to 2004, with FARSITE simulating where fires would have spread, and the fuel succession model updating fuels accordingly. In this way, fires simulated by FARSITE in one year could affect the spread and behavior of fires in subsequent years. By sequentially simulating fires for the 11-year period, a data set representing hypothetical pre-fire-season 2005 fuels was generated. This data set was compared with the actual landscape to quantify the cumulative effects of 11 years of suppression.

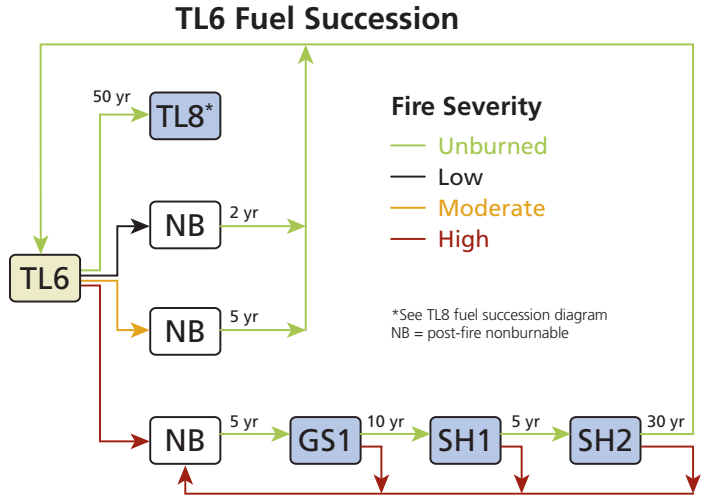

Figure 1. Sample diagram describing 1 of the 22 dynamic fuel succession models, this one for the Timber Litter 6 (TL6) fuel model. Depending on fire severity and time since fire, succession proceeds to other fuel types. See table 1 for fuel model descriptions.

One way these cumulative effects were quantified was with the Fire Return Interval Departure (FRID) index. This index quantifies the departure from the pre-Euro-American settlement fire return interval (Caprio et al. 2002; van Wagtendonk et al. 2002) and is computed as the time-since-last-fire divided by the characteristic fire return interval for the vegetation type. The characteristic fire return interval can be determined from published literature and fire history chronologies reconstructed from the tree rings of fire-scarred trees (Caprio and Lineback 2002). Through the use of Geographic Information System (GIS) software, FRID estimates have been spatially mapped and areas with the highest values of FRID or "ecological need" are typically prioritized for fuel management and restoration activities. The index is also useful as a coarse filter for measuring progress and setting maintenance priorities in ecological restoration; decreases in FRID values reflect improved ecosystem condition (Caprio and Graber 2000). Two FRID maps represented the end of the study time period, one for the simulated landscape and one for the actual landscape. By comparing the before and after maps of FRID, we were able to summarize the cumulative impacts of suppression on ecological condition during 1994–2004 (fig. 2) (Miller and Davis 2009).

Consequences of fire suppression

The impacts of suppression on fire return interval departure were surprisingly substantial, especially since they were accumulated

Table 1. Fuel models represented in Yosemite and Sequoia–Kings Canyon National Parks

Fire Behavior Fuel Model*	Description	Percentage of Watershed (1994 basis)	
		South Fork Merced	Upper Kaweah
Grass 1 (GR1)	Short, sparse dry climate grass	<0.1	<0.1
Grass 2 (GR2)	Low load, dry climate grass	0.2	1.4
Grass 4 (GR4)	Moderate load, dry climate grass	0.0	0.0
Grass-Shrub 1 (GS1)	Low load, dry climate grass-shrub	0.0	<0.1
Grass-Shrub 2 (GS2)	Moderate load, dry climate grass-shrub	<0.1	2.6
Shrub 1 (SH1)	Low load, dry climate shrub	0.0	0.0
Shrub 2 (SH2)	Moderate load, dry climate shrub	0.6	1.7
Shrub 5 (SH5)	High load, dry climate shrub	0.3	4.2
Shrub 7 (SH7)	Very high load, dry climate shrub	1.0	2.3
Timber Litter 1 (TL1)	Low load, compact conifer litter	3.5	6.6
Timber Litter 2 (TL2)	Low load, broadleaf litter	1.2	3.5
Timber Litter 3 (TL3)	Moderate load, conifer litter	19.0	8.9
Timber Litter 4 (TL4)	Small downed logs	10.1	10.4
Timber Litter 6 (TL6)	Moderate load, broadleaf litter	1.1	3.8
Timber Litter 7 (TL7)	Large downed logs	13.2	12.3
Timber Litter 8 (TL8)	Long needle litter	16.0	4.8
Timber Understory 1 (TU1)	Low load, dry climate timber-grass-shrub	3.3	2.3
Timber Understory 5 (TU5)	Very high load, dry climate timber-shrub	12.2	11.8
Nonburnable	N/A	18.3	23.3

*Source: Scott and Burgan 2005.

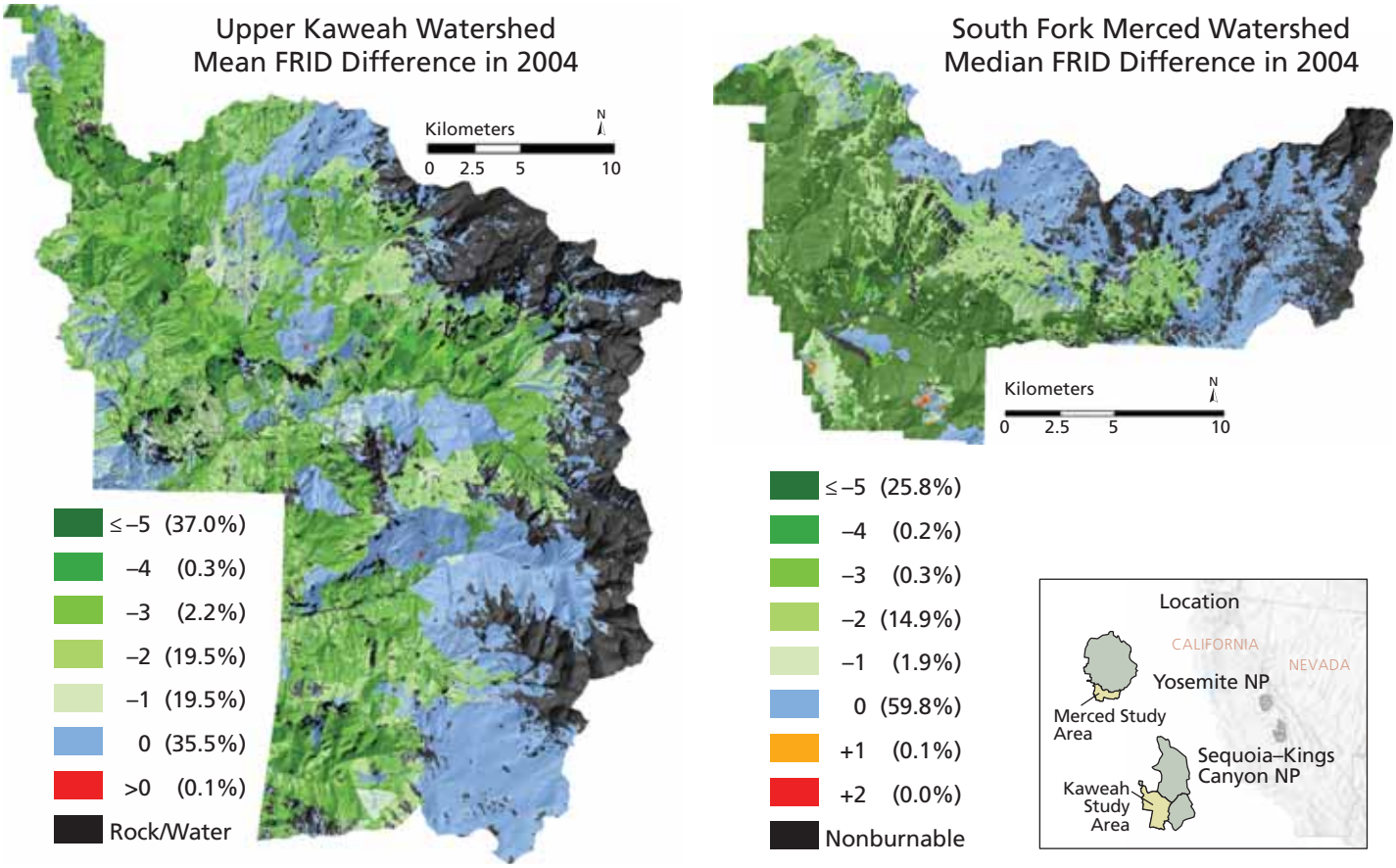

Figure 2. Difference in the Fire Return Interval Departure (FRID) index between the actual and modeled landscapes for the Upper Kaweah watershed and the South Fork of the Merced watershed. Negative values indicate that the modeled landscapes had lower FRID values (improved ecological conditions) than the actual landscapes.

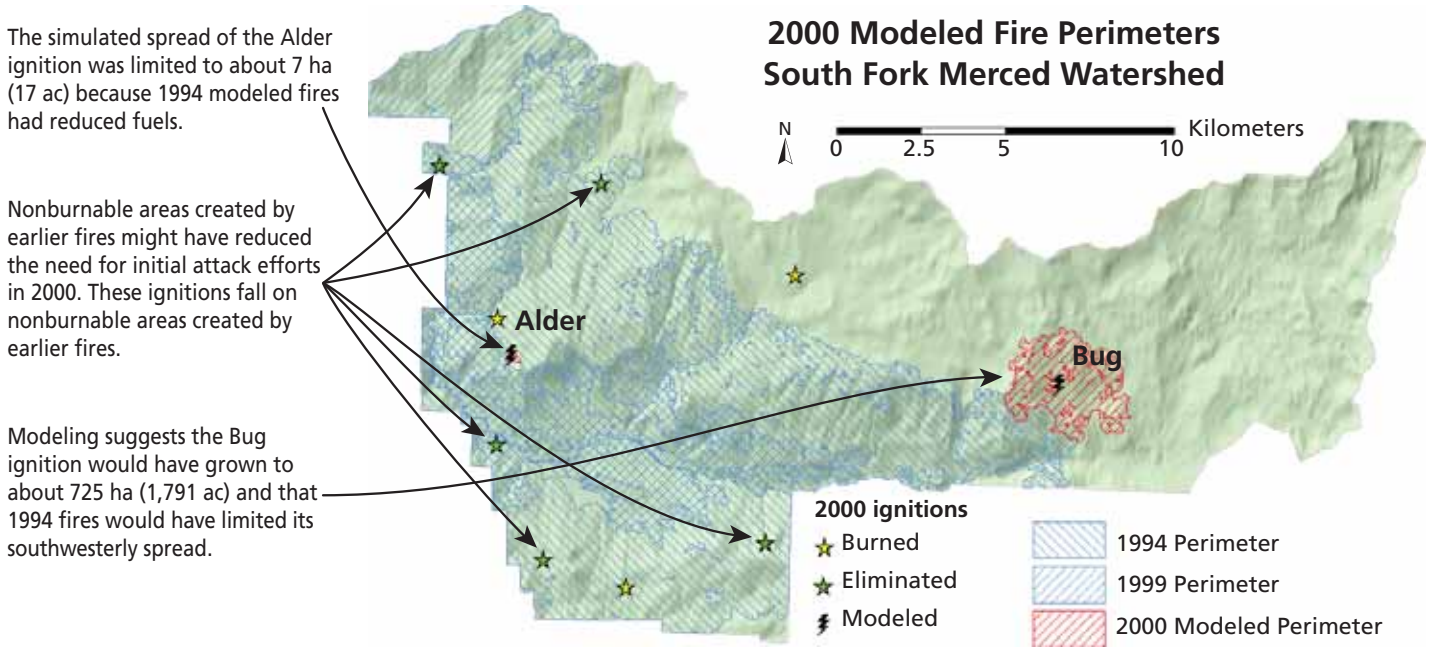

Figure 3. Analysis from the year 2000 for the South Fork of the Merced watershed illustrates how spread of fires was affected by fires simulated in previous years.

over a relatively short period of time (11 years). If all the ignitions simulated had been allowed to burn in the Upper Kaweah watershed in Sequoia–Kings Canyon, the average FRID would have improved from a value of 4.3 to a value of 0.3 (fig. 2). For the South Fork of the Merced watershed, the average FRID would have improved from the actual value of 4.5 (high departure) to a value of 1.8 (low departure) (fig. 2).

Simulations also showed that past fires have a major impact on how and where future fires burn. The simulations revealed a number of instances where the growth of fires would have been curtailed by burned areas if fires had not been suppressed, demonstrating how fires can create barriers to future wildfires in the form of fuel breaks (fig. 3). Fuel breaks can be helpful to managers when fighting future undesirable fires or when allowing desirable fires to burn. For example, knowing there is a fuel break in place between an ignition and a point of value such as a historical cabin might make managers more confident about making the decision to let an ignition burn.

The simulations illustrated yet another hidden consequence of suppression. Many ignitions may never have occurred because they were located in areas where an earlier modeled fire would have left little fuel remaining on the site. In the South Fork of the Merced study area, 5 of the 10 ignitions initially identified as having significant potential for spread were eliminated in this fashion.

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In the Upper Kaweah study area, 9 were eliminated for this reason. This finding may resonate with many fire managers who have seen that lightning ignition patterns are not entirely random. Fire records include many examples where fires in the same general location are suppressed year after year.

The ignitions simulated in the South Fork of the Merced study area burned a total of 33,756 acres (13,661 ha; 43.5% of the watershed). In the Upper Kaweah study area, simulated fires burned a total of 137,793 acres (55,765 ha; 61.5% of the watershed) (table 2). Some of these fires were much larger than what would likely be acceptable to land managers or the public. For example, simulations suggest that approximately 20% of the South Fork of the

Table 2. Area burned in retrospective simulations of suppressed lightning-caused ignitions in the two case study watersheds

	South Fork Merced			Upper Kaweah		
	Number of Simulated	Area Burned		Number of Simulated	Area Burned	
Year	Ignitions	Acres	Hectares	Ignitions	Acres	Hectares
1994	3	15,327	6,203	2	1,164	471
1995	0	0	0	4	7,709	3,120
1996	0	0	0	1	1,040	421
1997	0	0	0	0	0	0
1998	0	0	0	1	27	11
1999	1	16,825	6,809	1	3,301	1,336
2000	1	1,604	649	0	0	0
2001	0	0	0	3	71,317	28,862
2002	0	0	0	2	1,762	713
2003	0	0	0	6	22,414	9,071
2004	0	0	0	3	29,056	11,759
Total	5	33,756	13,661	23	137,793	55,765

Merced watershed would have burned in 1994, another 20% just five years later in 1999, and some fires would have escaped the park boundary. In the Upper Kaweah, almost a third of the watershed would have burned in 2001. Although fires of this size are not unprecedented (Caprio 2004), in reality many of the modeled ignitions would have warranted management actions to confine them. Although confinement strategies were not considered in this study, a fruitful extension of these methods would be to apply more realistic "appropriate management response" scenarios and examine the effect on FRID.

Conclusions

The potential negative consequences of those fires that may have become quite large are extremely important and should be considered along with the potential positive consequences that might have occurred. However, these methods are not intended to second-guess suppression decisions. Suppression decisions are based on a complex suite of factors present at the time of ignition and are made without the privilege of hindsight or the certainty about weather conditions that exists after the fact.

Both parks are almost entirely wilderness and have fire management plans with extensive zones where the option of using natural ignitions to return fire to the landscape exists. Suppressing lightning-caused wildfires runs counter to the goal of protecting natural and untrammeled qualities in wilderness. Ideally, the decision to suppress or not to suppress a fire considers the possible consequences of allowing a fire to burn *as well as* the consequences of suppression. The research described here provides information about the consequences of suppression that could help inform decisions about future ignitions. Furthermore, knowledge of where nature would have treated an area with fire can help managers set priorities for fuel projects and, possibly, analyze opportunities for restoring "lost" ignitions with prescribed burns.

While parks and other protected areas strive to restore the natural role of fire and, in the case of wilderness, also protect untrammeled qualities, they must also protect a variety of other societal values, such as air quality and public safety. Retrospective analyses can also be applied to assess other consequences of suppression. The cumulative effects of suppression could be quantified in terms of smoke emissions over time or potential fire intensities. An understanding of what was gained and what was lost when each ignition was suppressed in the past is needed before managers can effectively communicate these trade-offs to the affected public and neighboring governmental entities. Further, this retrospective modeling approach is a quantitative method that park managers can use to better understand, measure, and track the cumulative effects of their decisions from year to year (Davis et al. 2010).

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