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## Behavior Modification: Tempering Fire at the Landscape Level

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With fire excluded for the past century, the potential for large and severe fires increases in the forests of the Sierra Nevada.  
Photo by USDA Forest Service.

## Behavior Modification: Tempering Fire at the Landscape Level

### *Summary*

With a history of management choices that have suppressed fire in the West, ecosystems in which fire would play a vital role have developed tremendous fuel loads. As a result, conditions are prime for fires to grow large, escape attack measures, and become catastrophic conflagrations that damage watersheds, forest resources, and homes. With a quiver of treatment options, land managers have successfully used prescribed burning and thinning to modify landscapes at the stand level. But planning treatments to modify fuel build up on a patch of forest is vastly different than planning treatments that could modify fire's spread over larger landscapes.

Using information specific to a site, such as fuels, topography, and weather, simulations are run to identify the pathways fire would likely follow, the elements that would cause a fire to grow from moderate to severe, and the treatment options that would best modify the fuel load present. The simulations identify the best placement of treatment units and number of units on a landscape. Little is known about how long treatments will last, but studies suggest the benefits are limited to 10 to 15 years. To achieve desired effects in tempering fire's behavior, land managers must apply optimally placed treatments at a rate of 1% to 2% per year.

## Key Findings

- The pattern of fuel treatment units on a landscape is critical. Fuel treatment patterns placed optimally on a landscape (along a fire corridor) are roughly twice as efficient at changing large fire growth as random arrangements.
- When arranged in an optimal pattern, fuel treatment must occur at a rate of 1% to 2% per year to achieve reductions in large fire sizes or growth rates. The rate of treatment must produce treated area faster than the rate of plant regrowth and new fuel accumulation.
- Using sufficient treatment rates, the benefits of a fuel treatment program take about 1 to 2 decades to achieve.
- Long-term programs of fuel treatment involve maintenance of previously treated areas as well as implementation of new treatment units. The location of the treatment areas as they relate to the major corridors for fire spread are the most important factor in determining whether to maintain them.
- Variation in treatment unit sizes has the least impact on modifying large fires compared to treatment pattern and rate of treatment.

With a history of management that suppressed fire, lands in western North America bear conditions that foster the growth of large or “problem fires”—conflagrations that escape initial attack and spread far from where they start. Fire hazards, as a result, are greater, and threaten values—the safety of our homes and communities, the protection of our watersheds, and the beauty of our natural lands. Adding to the hazard, homes are built in ever greater numbers at the wildland-urban interface (WUI). In recent years, catastrophic fires have grabbed public attention, stimulating renewed interest in fuel treatments and prompting new research studies. Mark Finney, fire science researcher with the USDA Forest Service’s Missoula Fire Sciences Laboratory, has invested much of his time in providing answers and offering strategic planning tools to modify fire behavior.

### Complexities of a conflagrant nature

“Fuel,” Finney offers, “is the only element of fire behavior that is manageable, since weather and topography are beyond human control.” Understanding how weather, topography, and fuels play a role in allowing fire to blow up is vital, but changing the character of fuels on the landscape and the arrangement of fuels offers the only possible means to resist a fire’s ability to turn into a disaster. To conduct experiments that haven’t been possible on actual, large-scale landscapes, Finney has developed a method to map how fires develop. But before he models fire behavior on a particular landscape, Finney

looks at the real world concerns of stakeholders and those charged with managing the land. Equipped with a quiver of treatment options, having assembled data on weather patterns and plant species that comprise the fuel load on a given landscape, Finney places himself in the land manager’s role, with questions on predicting where fire will go, what fire will do, and how to curb fire’s energy so it can’t get out of hand.

### Trial by (facsimile of) fire

A landscape of ponderosa pine forest located near Flagstaff, Arizona, historically burned at short-intervals, removing fuels on the ground, allowing plants to carry out their life histories. As management choices in the past continually prevented fire, this ponderosa pine forest now experiences, under extreme conditions, crown fires as the dominant fire pattern.

A California landscape in the Stanislaus National Forest in the heart of the central Sierra Nevada contains a mix of vegetation and ownership—its western edges representative of the wildland-urban intermix of the foothills. With fire excluded for the past century, surface and crown fuels now make a relatively continuous fuel complex with the potential for large and severe fires under extreme conditions. The foothills of the central and northern Sierra Nevada have already experienced these kinds of fires, catastrophic events that have resulted in losses and costs in the hundreds of millions of dollars.

What is the best management plan to reduce fuels on each of these landscapes? Where should treatment



To study how fire behaves on different landscapes, Finney set forests afire—by simulation (IJWF 16:712-727).

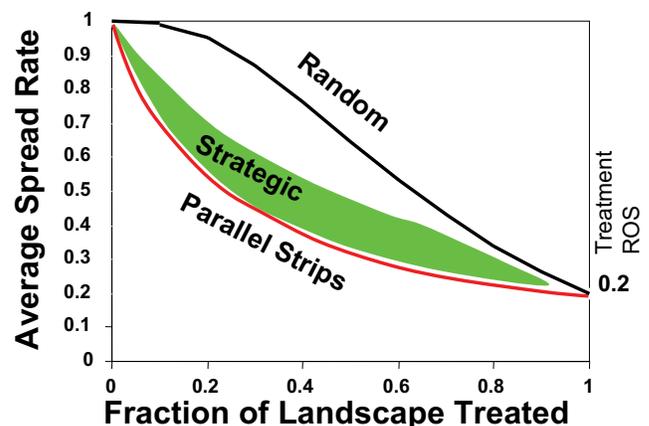
sites be situated on the landscape to obstruct fire growth? What rate should treatments be applied to produce cumulative change in fire behavior? How fast does plant matter regrow? How do areas excluded from treatment possibilities—due to private ownership or wilderness designation, for example—affect treatment benefits? To study the California, western Montana, and eastern Washington sites that represent different forest conditions in the western United States, Finney set them afire, by simulation that is.

Using the Forest Vegetation Simulator (FVS) with its Fire and Fuels Extension (FFE), Finney and his collaborators were able to plug in critical variables: species types, tree diameters, stand height, canopy cover, canopy base height, canopy bulk density, fuel pools, treatment history, vegetation growth rates, topography, historical weather conditions that have produced fire spread directions and rates, wind speeds, and moisture levels. Then they ignited a spot and watched fire burn the land. Next, in another simulation, they selected treatment options and directed them at the modeled landscape to see which treatment or treatment combinations could weaken a fire’s ability to grow into a problem conflagration.

To test options and patterns, Finney ran comparisons that placed treatment units using optimal (along fire corridors, for example) versus random

placements. The simulation models were able to calculate the impacts of treatments in terms of how fast a fire spread, how large a fire grew, and how likely an area would burn once fire grew large or escaped initial attack. The difficulty for planning managers in placing units and determining unit sizes, Finney found, is that actual landscapes, as opposed to unit sizes developed for models, contain complex variations in fuels, topography, wind direction, and fuel moisture. “Under complex conditions, the size and orientation of a given treatment is only efficient in the context of other possible units encountered immediately before and after the fire moving across the landscape,” Finney notes. “Each unit modifies the path of fire into succeeding units.”

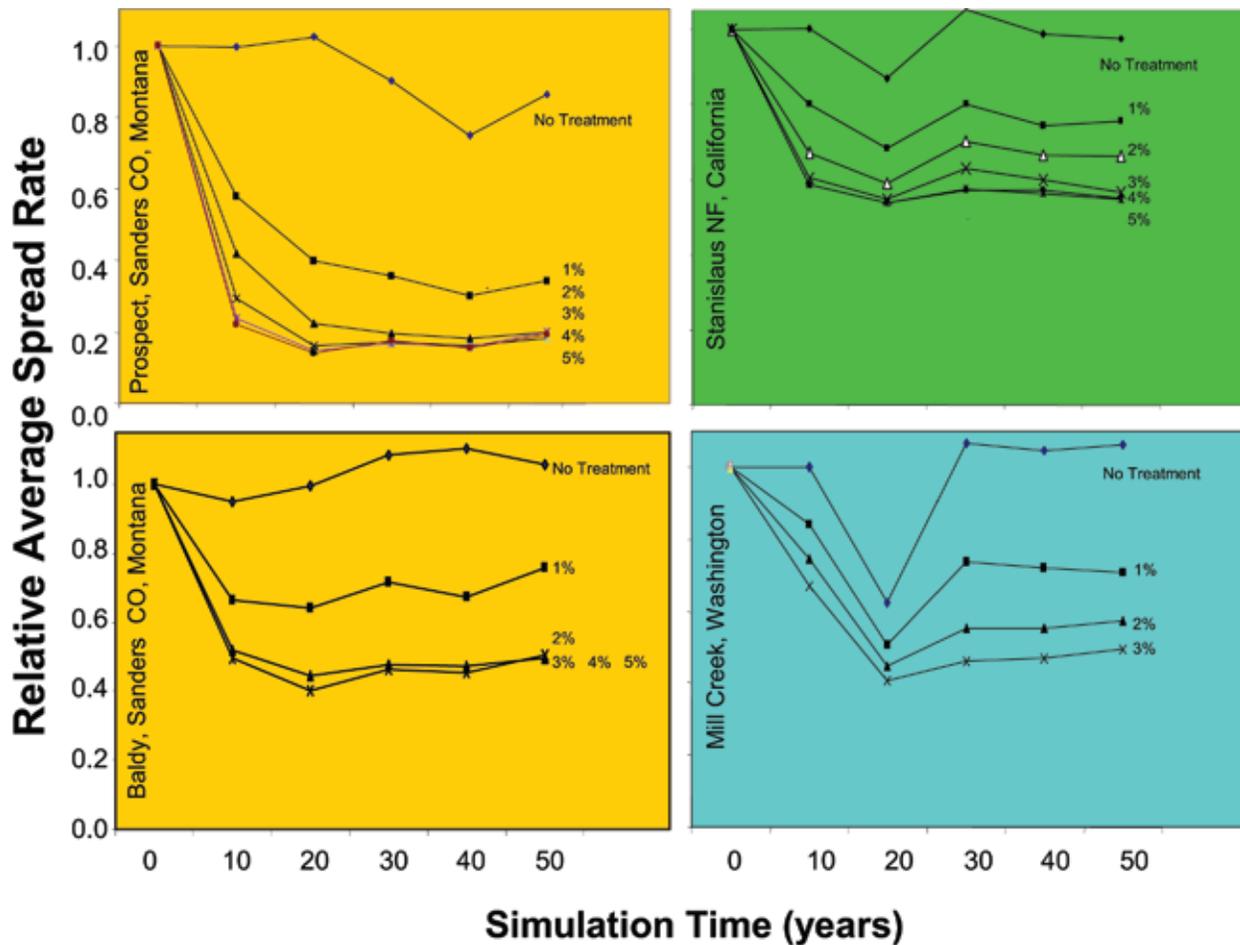
To accommodate how fire behaves among multiple units, the algorithm Finney developed divides the landscape into a series of parallel strips oriented perpendicularly to the main fire spread direction. For each strip, beginning with the upwind strip that was ignited, fire growth and minimum travel routes are computed. The procedure identifies treatment units within the strip that have the best sizes and shapes for efficiently retarding fire growth.



Optimally arranged treatment units require half as many as randomly placed units to reduce fire growth.

## Living with the learning

When hoping to modify the behavior of a potentially voracious fire, the good solutions, according to Finney, seem to be “greedy” ones. Greedy solutions, he explains, are chosen from only locally available information—but information that considers how fire moves across the landscape. Places where fire moves easily are distinguished



To achieve desired effects in tempering fire's behavior, land managers must apply optimally placed treatments at a rate of 1% to 2% per year (IJWF 16:712-727).

from places where fire spread is difficult. “These pathways are found by simulating fire movement across the landscape and account for the complex spatial patterns of the fuels, topography, and wind direction that are not local at all,” Finney explains. After identifying the places where fuels, topography, and wind direction allow fire to move easily, solutions can be made that consider only these local pathways. The advantages of these solutions are twofold: faster computation times in the model because fire growth does not have to be simulated far downwind from the strip that was first ignited and, more importantly for fire management applications, the solutions place a treatment unit on a locally major pathway of fire movement, which increases the likelihood that a well-placed treatment unit will be near a random ignition source on the landscape. Rather than reworking and modifying hundreds of thousands of acres on a landscape-wide level, at great cost, labor, and time, Finney has determined that applying annual

treatments strategically can produce the desired effects in modifying fire's behavior. Fuel treatments can be designed to decrease burn probability by considering both the treatment used at the stand level and at the landscape level.

To achieve a pattern across a landscape that will inhibit fire's behavior, land managers must make the annual rate of treatment or maintenance high enough to outpace the rate that vegetation will regrow, adding new fuels. Little is known about how long treatments last, but a few studies suggest that the benefits are limited to 10 to 15 years. Using the best treatment options (e.g., thinning, prescribed burning), fuel treatment arrangements that are optimal in disrupting the growth of large fires require that at least 1% to 2% of the landscape be treated each year. Even if spot fires jump into units that have been treated, an extensive landscape pattern of treated units would interrupt any new fires. Simulations showed randomly arranged units with the same treatments applied as

used in an optimal pattern required twice as many units to reduce fire growth.

Timeframes for treatment longevity mean that land managers must make a substantial effort for roughly two decades to realize fuel treatment benefits that can temper fire's behavior. Since higher treatment rates seemed to accelerate the production of benefits, higher rates might be desirable in the first decade followed by later decreases. Variation in treatment unit sizes had the least impact on modifying large fires compared to treatment pattern and rate of treatment. In the absence of spot fires, large and small units were found to produce similar reductions in fire sizes, spread rates, and burn probabilities. Small units, though, may not effectively block fire through large corridors where fire moves easily.

As with rapid recovery of fuels after treatment, limitations on the placement of treatment areas reduce the effectiveness of a plan to inhibit large fires. Simulations showed restrictions on placing treatment areas (imposed for a variety of reasons, including concern for wildlife habitat, proximity to streams or rivers, road access, budget limitations, or ownership), despite the need for treatment at these locations, decreased the effectiveness of an optimal treatment by 50%. Treatment restrictions amounting to more than about 40% of a landscape would diminish any advantage an optimal solution would achieve over purely random treatment placement. If land managers want to reduce large fires, collaboration with all concerned parties would be necessary to permit treatment at locations necessary to achieve landscape-level changes that would prevent fire from raging out of control. Under healthier conditions, fire could return to its habitat.



Restrictions on placing treatment areas, such as private land ownership, decrease effectiveness of optimal treatment by 50%.

### **Management Implications**

- When hoping to modify the behavior of a large fire, the best solutions use locally available information on where fire movement is made easy by the alignment of fuels, topography, and wind direction. Treatment units, as a result, are placed on a locally major pathway for fire.
- Land management activities that exclude areas from treatment can completely remove the benefit of an optimal treatment strategy. Restricting treatment in necessary areas reduces the effectiveness of optimal treatment patterns by 50%. If land managers intend to achieve reductions in large fires, collaboration with all concerned parties would be necessary to achieve landscape-level effects.

### **Further Information: Publications and Web Resources**

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All photos and graphics are used courtesy of Mark A. Finney and the USDA Forest Service unless otherwise noted.

## Scientist Profile



**Mark A. Finney** is a Research Forester with the USDA Forest Service, Rocky Mountain Research Station, in the Fire Behavior Project at the Fire Sciences Laboratory in Missoula, Montana. His current research interests are fire behavior and fire behavior modeling. Before taking his current position, he spent 7 years as a research scientist and consultant, and 2 years as a fire ecologist with Sequoia National Park. He received his Ph.D. in wildland fire science from the University of California at Berkeley in 1991 studying prescribed fire and effects in the coast redwood forests. He earned his M.S. in fire ecology

at the University of Washington in 1986 working on fire history and effects in North Cascades National Park. He has a B.S. degree in forestry from Colorado State University (1984).

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## ***Cumulative Effects of Fuel Management on Landscape-Scale Fire Behavior and Effects***

**JFSP Project # 01-1-3-21**

### **Purpose of this opinion piece**

Managers Viewpoint is an opinion written by a fire or land manager based on information in a JFSP final report and other supporting documents. This is our way of helping managers interpret science findings. If readers have differing viewpoints, we encourage further dialog through additional opinions. Please contact Tim Swedberg to submit additional viewpoints ([timothy\\_swedberg@nifc.blm.gov](mailto:timothy_swedberg@nifc.blm.gov)). Our intent is to start conversations about what works and what doesn't.

### **Problem**

Earlier works (Finney, 2001a, Finney, 2001b) showed that patterns of disconnected fuels treatment patches that overlap in the direction of maximum spread (head fire) are theoretically effective in changing overall forward fire spread rate. This line of research is commonly referred to by fuels practitioners as the "Finney Blocks" concept. This study builds on those earlier works to explore a practical application of the concept, namely in locating fuel treatments across the landscape.

This study addresses placement, size, and longevity of fuels treatments at a landscape scale. Determining where to place fuels treatments across the landscape, how big those treatments should be, and how often to repeat treatments have all proven difficult questions to answer for fuels specialists working in diverse landscapes. Trying to find where the biggest impact for the investment can be realized when planning fuels treatments is the key problem area that this study addresses.

### **Application by Land Managers**

The overall simulation system used in the case studies that were intended to determine the optimum placement and timing of fuels treatments across a large landscape are likely too complex for the journeyman fuels specialist to perform on their own. These case studies required a team of 3-5 experts with expert knowledge of fire modeling, stand development, fuels treatment prescriptions, and development and analysis of spatial-temporal data. The computing facilities required for the work also greatly exceed those of most land management facilities, thus the ability to "optimize" fuel treatments for specific landscapes using the techniques described in this project is likely out of the realm of possibility for most units.

The incorporation of the fuel treatment optimization model in version 3.0 of FlamMap does make the results of the study accessible to managers for use on individual planning areas. The difference is the fire vegetation simulator is not available to “grow” the forest post treatment and continue to define “optimal” solutions, thus the optimization is performed only for a snap-shot in time and does not factor in treatment longevity and optimization patterns over a given time period.

The most obvious application for the applicable results (FlamMap fuels optimizer) is in strategic planning of fuels programs. This study indicates that for western fuel types, a fuels program may want to achieve treatment of 10% to 20% of the landscape in order to achieve a measurable disruption on fire growth. The optimization model also would indicate that repeat treatments within about a 50 year period is not as desirable as moving those treatment areas throughout the landscape.

This and several related studies also have application at the project level, especially in terms of providing a framework to evaluate fuels treatment options. Ager et. al. (2006a), introduces the Fireshed process within ArcGIS which can serve as a starting point for determining fuels treatment sizes and placement. This is a data intensive process and is likely best suited for large to very large project areas such as watershed or district/forest-wide assessments. Another work by Ager et. al. (2006b) uses a similar approach to this study by Finney, but it adds the concept of expected net value change by translating the outputs of the simulation into economic terms. Ager et. al. (2006b) uses a hypothetical landscape that includes potential losses to ecological and urban interface values as well as potential benefits to ecological values and unlike this work by Finney which focuses on minimizing fire spread across the landscape, Ager et. al. looks at the more pressing issue of focusing attention on those areas of the landscape that are most valuable.

This study along with others (Finney 2006, Finney 2001a, Finney 2001b, Finney 2004) are collectively applicable to supporting the idea of optimal placement of fuels treatments. For smaller project areas, these studies are applicable to the cumulative effects sections of a fuels specialists report when tying a specific project into the overall fuels program strategy. The “Finney Blocks” concept is well supported in these simulations as well as in case studies (Graham et. al 1999, Pollet and Omi 2002, Graham 2003).

One must be mindful however that this body of work does not consider spotting potential or resistance to control when determining optimal size and placement of fuels treatments. Fuels specialists should use caution when interpreting results of these simulations and consider whether spotting potential would be such that the modeled maximum treatment size is invalid.

Another questionable assumption is that risk from fire will be reduced by decreasing the rate at which fires travel across the landscape. This is a similar assumption to that made by Valdez & Dean (2001), who’s study was very similar in design to this one in

that the measure of success for fuels treatments was to slow rates of spread across the landscape through targeted fuels treatments. The basic problem with this shared assumption is that fire tends to travel fastest in the lighter fuels (grasses, brush) where as it travels slowest in the heavier fuels (timber litter, slash). In terms of threat to values, practical experience and research (Cohen 2000) has shown that lighter fuels are less of a threat than heavier fuels when found adjacent to the values we wish to protect. Heavier fuels also produce higher intensities and longer durations (continue to burn over several burning periods), thus their resistance to human control are factors that should be considered when discussing risk. Lighter fuels while producing faster moving fires, also produce lower intensity fires that are shorter in duration, often lasting only a single burning period. Thus if our objective is to protect values at risk, the notion that slowing down fire spread across the landscape will result in better protection of values may be flawed.

The fire manager must also consider that these modeling schemes assume that no control efforts will influence the outcome, when we know for certain that we are likely going to maintain at least some level of firefighting capability locally and nationally. If the analyst applies the fire suppression principle of “Speed and Force”, we need to consider rate of spread and intensity together in order to quantify whether the Speed and Force of a modeled fire scenario exceed the Speed and Force of our management capabilities. Generally speaking, fuel treatment “optimization” models like this one that considers only a single fire behavior characteristic (rate of spread) should be suspect and careful consideration needs to be taken as to whether the single focused treatment scheme is robust enough for the fuels problem at hand. Analysts should ask if given the mix of fire management resources available, will we be able to control the faster moving, low intensity fire easier than the slower moving, high intensity fire? If the faster low intensity fire is preferable, then a modeling scheme that considers intensity rather than rate of spread should probably be considered.

The design of these simulations use fire spread as the fire behavior variable that measures success, a reduction in which is assumed to be the more favorable outcome. In practical terms, a fuel bed that is characterized by slow moving, high intensity fires that are beyond our ability to control may be a bigger problem than a flashy fuel bed characterized by fast moving, low intensity fires. Care should be taken to insure the right conclusions are drawn for the particular landscape and set of circumstances being evaluated.

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