Poster Session

Use of Aerial Photography for Fire Planning and Suppression[1]

Alan H. Ambacher[2]

Abstract: Aerial photography has long been considered a valuable tool for wildland fire suppression activities. The Fire Resources of Southern California Organized for Potential Emergencies (FIRESCOPE) mapping program introduced the use of aerial photography as a critical component of an integrated mapping program for daily emergency response for the community of southern California map users. The Oakland fire storm and the recent southern California fires are examples of multi-agency involvement that demonstrate the importance for current information of existing ground conditions. Aerial photography is one source for obtaining current information.

Western Federal agencies involved in fire protection, such as the USDA Forest Service, USDI Bureau of Land Management, and the National Park Service, use aerial photography as an information base to support fire planning and suppression in wildland areas. As Federal agencies became involved in the multi-agency effort through Fire Resources of Southern California Organized for Potential Emergencies (FIRESCOPE) to improve coordination and communication, the use of aerial photography as an information base was expanded into interface and urban fire response areas.

The FIRESCOPE mapping program was designed to provide fire service agencies with a consistent, standardized set of cartographic products derived primarily from National, State, and local government mapping programs. The value of the FIRESCOPE mapping program to partner agencies depended upon timely maintenance of operational data layers. Current aerial photography to create orthophoto bases for ensuring positional accuracy of data collected by the fire services, or used directly as an information layer, was deemed critical to the success of the mapping program. The FIRESCOPE program concluded that Federal or State aerial photo sources were not adequate to meet this critical demand for updated aerial photography. Other sources for aerial photography had to be developed, including the private sector companies. Fire service agencies now use geographic information systems, electronic vehicle maps, and other technology to supplement their mapping programs. Yet, the need for consistent current map information to support on-site multi-agency emergency management continues, evidenced during the Oakland fire storm as fire crews from areas throughout the West arrived to support the City of Oakland Fire Department. Aerial photography from a private photo company, such as Pacific Aerial Surveys, can be used to create a range of photo products to quickly update existing operational data; as record keeping documents; for strategic planning, fuel assessment, structure locations, and evaluation hazard potential; and to familiarize emergency personnel on existing ground conditions before entering an area.

Current and historical high resolution aerial photography is available at various scales and film emulsions from private companies. The photography is remarkably detailed, allowing for easy interpretation of ground features such as street patterns, access roads, drainage patterns, tank locations, water sources, buildings, parking lots, light and telephone poles, and vegetation characteristics and types. Historical aerial photography is an excellent source to evaluate land use change that has occurred over large areas or individual sites.

Photo Laboratories

Aerial photo negatives for Federal agencies are stored at the Agricultural Stabilization and Conservation Service (ASCS) Aerial Photography Field Office in Salt Lake City, Utah, and the Earth Remote Observing Satellite (EROS) Data Center in Sioux Falls, South Dakota. Although these laboratories have emergency response plans to create aerial photo products, the currency and scale of the photography is not acceptable for information needs by fire personnel during or after a major interface incident. Also, it is impractical to expect these laboratories to respond within the first few hours of an incident to deliver aerial products to fire personnel.

Private laboratories, such as Pacific Aerial Surveys, located within or near the immediate area of concern can provide digital or hard copy aerial products from their library stock of aerial photography. By using the information network with other aerial photo firms and the government photo labs, Pacific Aerial Surveys can coordinate deliveries of aerial photo products within hours after receiving the initial request.

Photo Libraries

Pacific Aerial Surveys maintains in its photo libraries current aerial photos of the greater Bay Area, Monterey, Sacramento, Redding, and selected Los Angeles area counties.

[1] An abbreviated version of this paper was presented at the Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems, February 15-17, 1994, Walnut Creek, California.

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Pacific Aerial Surveys' corporate office is located in Oakland, California, where all Company film is stored. Sales offices are located in Van Nuys, Redding, and Monterey, California.

Private aerial photo companies have photo-equipped planes and calibrated aerial camera systems with 3.5-inch, 6-inch, 8.25-inch, or 12-inch lens ready for immediate mission mobilization. Other sensors can also be flown in these airplanes. Most companies now use Global Positioning Systems (GPS) technology to control photo exposure stations so coordinate information and not maps need only be transmitted to a company from a fire command center for a flight to occur.

Characteristics of Coastal Sage Scrub in Relation to Fire History and Use by California Gnatcatchers[1]

Jan L. Beyers **Ginger C. Peña**[2]

Abstract: Plant cover and vegetation structure were examined at two inland coastal sage scrub sites differing in fire history and use by California gnatcatchers. *Salvia mellifera* and *Eriogonum fasciculatum* dominated one site; shrub cover on gnatcatcher–occupied plots averaged 50 percent greater than on unoccupied plots. At the other site, gnatcatcher-occupied plots had high cover of *Artemisia californica* and *Encelia farinosa* while unoccupied plots were dominated by *E. farinosa* alone and had half as much total shrub cover. Gnatcatcher territories at both sites had taller shrubs than unoccupied plots. Recently burned areas and areas with little regrowth were not used by gnatcatchers.

Coastal sage scrub is a fire-dominated vegetation type that has been largely converted to agricultural and urban uses in southern California. Less than 20 percent of the original area of this vegetation type probably remains (Westman 1981). The California gnatcatcher *(Polioptila californica)* lives only in coastal sage scrub in California and Baja California (Atwood 1993); because habitat loss jeopardizes its survival, it has been federally listed as "threatened."

Inland Riverside County contains numerous remnant areas of sage scrub. Studies of gnatcatcher habitat have been conducted in coastal Orange and San Diego counties, often by biological consultants working for developers (e.g., Bontrager 1991, Ogden Environmental and Energy Services Co., Inc. 1992), but relatively little is known about gnatcatcher requirements in inland areas (Atwood 1993). In conjunction with two ornithologists studying gnatcatcher nesting success, we undertook this study to help clarify the relationship between California gnatcatchers, coastal sage scrub, and fire history.

Methods

Two study sites were chosen in western Riverside County: the University of California, Riverside's Motte Rimrock Reserve, located in the hills near Perris, California, and Lake Mathews, a Metropolitan Water District storage reservoir near Riverside, California. Almost half of the Motte Reserve was burned in a fire in September 1979; much of the rest burned in June 1981. California gnatcatcher territories are found only in the 1979 burn area. We sampled four plots each in known gnatcatcher territories, in 1979 burn areas without gnatcatchers, and in 1981 burn areas. Plots without gnatcatchers were randomly selected; plots in territories were chosen so as not to interfere with gnatcatcher breeding activity. On each plot, four line-point transects were randomly chosen perpendicular to a baseline. Vegetation cover was measured every 0.5 m along each 25-m transect by dropping a vertical pointer and recording the identity and height of each species touched by the pointer. Sampling was done in late spring. At Lake Mathews, plots were located in unburned vegetation occupied by gnatcatchers, unburned vegetation without gnatcatchers, and in an area burned in 1990. Sampling procedures were the same as at Motte.

Results

At Motte, plots in the 1979 burn area used by gnatcatchers averaged 50 percent greater shrub cover than 1979 burn plots not in active use. Plots in the area burned in 1981 had little live shrub cover and were not used by gnatcatchers (*table 1*). At Lake Mathews, unburned plots used by gnatcatchers had almost twice as much cover as those not used, and *Artemisia californica* was an important component of the cover. Shrub cover was very low in the 1990 burn plots (*table 1*). Plots in bird territories had taller shrubs than unoccupied plots at both sites as well (data not shown).

Discussion

California gnatcatchers do not rely exclusively on California sagebrush (A*rtemisia californica*) in inland sage scrub, as they appear to do near the coast (Bontrager 1991). Gnatcatcher plots at Motte were dominated by black sage (*Salvia mellifera*) and California buckwheat (*Eriogonum fasciculatum*); those at Lake Mathews had about equal cover of California sagebrush and brittlebush (*Encelia farinosa*). Sites used by gnatcatchers averaged more than 50 percent shrub cover, similar to results tabulated by Atwood (1993). Recently burned sites were not used by gnatcatchers. Conditions that inhibit shrub recovery after fire, as apparently occurred with the 1981 fire at Motte, could reduce the amount of usable habitat available for California gnatcatchers.

[1]An abbreviated version of this paper was presented at the Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems, February 15-17, 1994, Walnut Creek, California.

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Table 1—*Average percent shrub cover (standard deviation) of plots at Motte Rimrock Reserve and Lake Mathews. "Total" may not equal the sum of each column because shrubs often overlapped.*

Species	Motte Site: Bird Plots[1] 1979 Burn		Non-bird Plots 1979 Burn		Non-bird Plots 1981 Burn	
Artemisia californica	4.3	(4.0)	6.1	(10.)	0	
Encelia farinosa	7.9	(10.2)	0.5	(0.9)	0	
Eriogonum fasciculatum	19.3	(16.3)	9.5	(8.2)	4.8	(2.0)
Salvia mellifera	31.5	(18.1)	24.3	(10.8)	0	
Total	62.9	(24.3)	40.4	(12.3)	4.8	(2.0)
	Mathews Site: Unburned		Unburned		1990 Burn	
Artemisia californica	33.6	(19.0)	1.3	(1.6)	0	
Encelia farinosa	28.2	(10.6)	31.1	(12.7)	2.5	(2.9)
Eriogonum fasciculatum	0.4	(0.4)	1.4	(1.4)	0.3	(0.5)
Bebbia juncea	0.7	(1.2)	0.1	(0.2)	2.5	(3.5)
Lotus scoparius	0		0		5.2	(7.3)
Total	62.9	(11.3)	33.9	(13.5)	10.5	(9.8)

[1] Bird plot denotes use by California gnatcatchers; non-bird plot denotes no use by California gnatcatchers in spring 1993. N=4 plots per category at Motte site; n=3 for burned plots at Mathews, n=4 for unburned plots at Mathews.

Acknowledgments

Permission to work at the Motte Rimrock Reserve was granted by Reserve Director Barbara Carlson, University of California, Riverside; she also provided information on gnatcatcher territories and safe sampling times. Metropolitan Water District allowed us to work at Lake Mathews. Dr. William O. Wirtz II and Audrey Mayer of Pomona College identified gnatcatcher territories at Lake Mathews. Carla Wakeman, Michael Oxford, and Peter Coy assisted with the vegetation sampling.

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The Quest for All-Purpose Plants[1]

Susan L. Frommer David R. Weise[2]

The Problem

The fire safety of a home in the wildland/urban interface is influenced by several factors—one of which is the presence and proximity of vegetation to the home. Landscaping may either provide a significant barrier to fire spread and thus potentially increase a home's fire safety or favor fire spread and reduce a home's fire safety. However, fire safety of vegetation is not the only criterion a homeowner or landscape designer uses when selecting plants for use in a yard. Other criteria include drought resistance, erosion prevention, and esthetics.

Many lists of "fire retardant" plants are available in trade magazines, newspapers, and from various public agencies like water districts and resource conservation districts. The bases of these lists are often unknown; fire safety ratings for a particular plant may vary appreciably from list to list, only the genus of the plant may be given with no species name, or the same species names keep appearing from list to list including even misidentifications and misspellings. For example, *Cupressus sp* is listed in one publication as being highly flammable (Baptiste 1992); however, *Cupressus arizonica* was rated as weakly flammable in France for the months of May, June, and October; not very flammable for July, August, and September; and moderately flammable in November (Valette n.d.).

Plant lists often fail to consider the fact that plants may be reasonably fire retardant (however it is defined) when watered but become more flammable when dry. Some plants have a natural ability to retain a higher fuel moisture content longer than others after the onset of the dry months, which prolongs their fire-retardant characteristics later into the dry season on unirrigated sites.

Furthermore, relying on only one attribute, flammability, as a guide to plant selection ignores the many other functions we expect from our landscape plants such as the abilities to control erosion on slopes, to shade our homes during the hot summers, to provide food for us and for wildlife, to conserve water, and to be esthetically pleasing. Some lists of "fire-retardant" plants have information about other desirable attributes, but there are enormous gaps in this information as well.

A Possible Solution

We propose to develop a preliminary set of techniques based on flammability tests for building materials to determine flammability and total heat release rates of intact vegetation, both green and dried. This information can then be used to devise a rating scale for relative "fire retardance" which then can be coupled with another series of ratings for water consumption, frost tolerance, climate modification, erosion control, wildlife habitat, etc. *Table 1* lists possible candidate species that meet criteria other than flammability. Information on fire retardance is often missing. This information will help homeowners, planners, plan checkers, and others to make intelligent and economical landscaping decisions based on the particular hierarchy of needs of each site. Once such a system exists, fire-safe landscaping decisions will have a stronger scientific basis.

[1] An abbreviated version of this paper was presented at the Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems, February 15-17, 1994, Walnut Creek, California.

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Table 1– ***Candidates for fire retardance tests with ratings for other desirable characteristics for landscape plants.***

Plant	Fr [1]	Wtr	Aes	Er	Oth
Oenothera berlandieri	?[2]	x	x	x	x
Cistus crispus	?	x	x	x	?
Olea europa	?	x	x	?	x
Rhus ovata	?	x	x	x	x
Correa 'Carmine Bells'	?	x	x	x	?
Muhlenbergia rigens	?	x	x	x	?
Rhagodia spinescens	?	x	x	x	?
Rosmarinus officinalis	?	x	x	x	x
Melia azedarach	?	x	x	?	x
Cistus salviifolius	x	x	x	x	?
Baccharis pilularis	?	x	?	x	?
Salvia microphylla	?	x	x	x	x
Myoporum 'Putah Creek'	?	x	x	x	?
Heteromeles arbutifolia	?	x	x	x	x
Verbena tenuisecta	?	x	x	x	?
Westringia rosmariniformis	?	x	x	?	?
Salvia greggii	?	x	x	?	x
Acacia redolens	?	x	x	x	?
Calystegia macrostegia	?	x	x	x	x
Cistus purpureus	?	x	x	x	?
Prunus ilicifolia	?	x	x	x	x
Sophora japonica	?	x	x	?	x

[1] Fr = fire resistant, Wtr = drought resistant, Er = erosion resistant, Aes = esthetically pleasing, Oth = other (wildlife habitat, food production, climate modification)
[2] x = suitable application, ? = information not available

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A High-Resolution Weather Model for Fire Behavior Simulations[1]

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Abstract: The typical computer fire model requires much greater spatial detail than current weather forecast models provide. One way to obtain more spatially descriptive weather simulations is to nest a fine model grid within a coarse one. This paper briefly describes a nested grid model with a fine grid interval of 2 km to simulate weather over Maui, Hawaii.

Wildland fire scientists today strive for greater detail, with the aid of computers. The computer is a virtual laboratory in which simulated fires burn through spatially complex fuel matrices, in response to weather and terrain conditions. The fire model sees the world as points on a regular grid. In one study of 2,000 ha on the Los Padres National Forest, California, grid points were spaced 50 m apart (Kalabokidis and others 1991). It is practically impossible to obtain vegetation, terrain and weather conditions for a grid this size by direct sampling. The vegetation grid was digitized from cover type maps and the terrain grid was obtained from a digital elevation model. But the study lacked the means to describe weather methodically on a fine grid. In fact, a fire weather model for the Los Padres study grid is theoretically possible, but computationally impractical.

Computer models are used to describe weather worldwide every day. The National Weather Service Medium-Range Forecast model (MRF) runs on a 160 km grid (approximately). At this resolution, the model hardly sees the Sierra Nevada Range. The spatial resolution is much better in the Nested Spectral Model (NSM), an as yet experimental model with a grid interval of 25 km (Juang and Kanamitsu 1994). The NSM is much more descriptive than the MRF (*fig. 1*), but it still lacks the detail needed for a fire simulation. We are developing a fire weather model for Maui, Hawaii that employs a 2 km grid interval. To our knowledge, it is one of the most spatially descriptive fire weather models of its kind.

An application of the Colorado State University RAMS code (Walko and Tremback 1991), the Maui weather model simulates dynamical changes in temperature, humidity, wind and precipitation fields, among others. Snapshots of the model fields every few minutes can provide weather information for fire simulations. The model grid is hierarchical. A National Meteorological Center coarse grid analysis describes the large-scale weather pattern over the state of Hawaii. Nested within this grid is a finer grid over the main islands of Hawaii. The densest grid is a 2 km grid centered on Maui (*fig. 2*).

We are just beginning the Maui modeling study. Preliminary results show tantalizing detail of the wind circulation over Maui. In one case, the model described locally stagnant winds where smoke dispersion tends to be a problem. We plan to verify the model to the extent possible, with a mesoscale network of automatic weather stations in Maui's central valley. We produced computer visualizations of the model output that show the motions of simulated air particles released at the 2 km grid points. Each particle is color-coded according to the wind speed at its location. The particles also leave streaks, similarly color-coded, that accentuate the flow field.

The model calculations are not trivial. It takes about 12 hours of computer time to produce a 12 hour simulation on a 100 Mhz workstation. The model physics and the number of grid points require a powerful number cruncher. But computers no doubt will run faster, and spatially detailed fire weather information is needed.

[1]An abbreviated version of this paper was presented at the Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosyystems, February 15-17, 1994, Walnut Creek, California.

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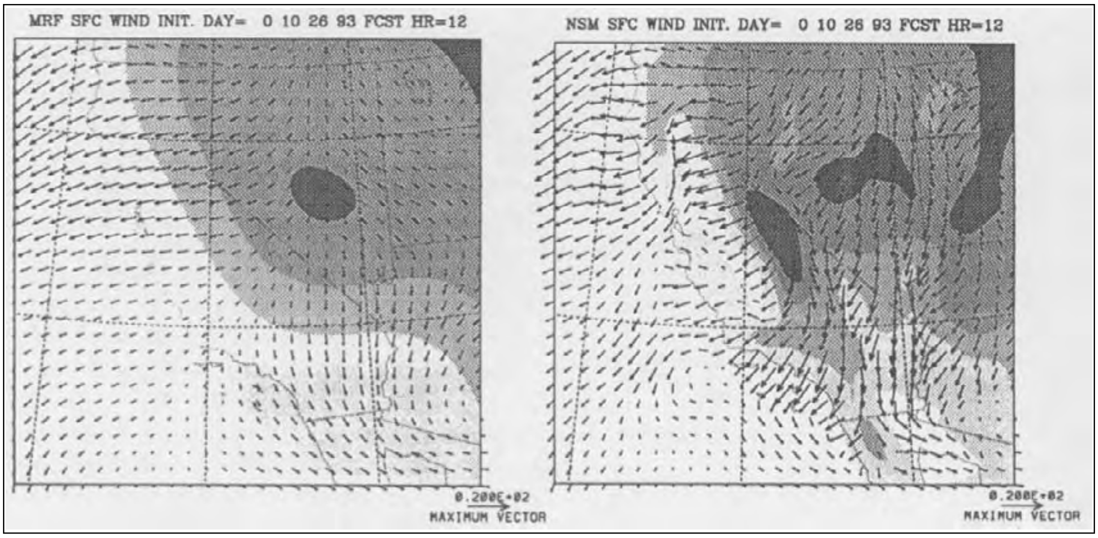

Figure 1–A comparison of the Medium-Range Forecast (MRF; left) and Nested Spectral Model (NSM; right) forecasts. The gray scale depicts topographic elevation bands, and the vectors represent the wind field.

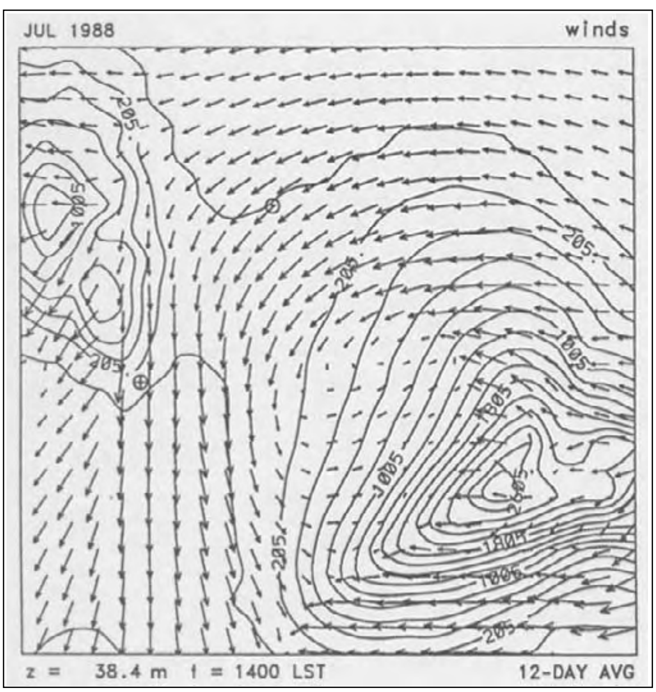

Figure 2–An average of the flow patterns at lower levels in July 1988 clearly shows an eddy on the lower northwestern flanks of Haleakala, Maui.

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Using a Geographic Information System (GIS) to Assess Fire Hazard and Monitor Natural Resources Protection on the Mount Tamalpais Watershed[1]

Thomas H. Gaman **Philip Langley**[2]

A natural resource management geographic information system (GIS) was developed that has proven useful in urban interface fire hazard mitigation planning and natural resource protection. A consultant team, selected to prepare the Vegetation Baseline Studies and Management Plan for the Mount Tamalpais Watershed in Marin County, California, obtained data from a variety of sources to create 25 data layers using BASEMAP 2000 GIS. The system provided a practical means for spatial data analysis and storage. It was also used extensively for graphic map production for the 20,000-acre watershed of the Marin Municipal Water District and the Marin County Open Space District.

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[1]An abbreviated version of this paper was presented at the Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems, February 15-17, 1994, Walnut Creek, California.

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Homeowner Intervention in Malibu[1]

Tom Gardner[2]

The Old Topanga Fire arrived in the Malibu neighborhood of upper Las Flores Canyon after 3 p.m. on Tuesday, November 2, 1993. Virtually every home survived the initial 10-minute passage of the flame front, but nearly all experienced a rain of hot embers that continued past dawn on Wednesday. One surviving home was protected by pool water, Class A foam concentrate, and a fire pump designed for home-owners living in the wildland/urban interface (*fig. 1*). This Malibu resident is the first known civilian to save a structure from wildfire using Class A foam technology. The fire pump, a Defender Foam System model #501 manufactured by Brushfire Hydrant Co. in Walnut Creek, California, was delivered in March 1991 (*fig. 2*). The system sustained extensive damage by the fire, but never failed during 6 hours of operation. The original design was awarded United States patent 4,671,315 in 1987 as the portable brushfire hydrant. When the patent expires in 2004, the surviving system will be offered to the Smithsonian Institution.

Figure 1–A home located in upper Las Flores Canyon, Malibu, California, that survived the Old Topanga Fire because of homeowner preparations.

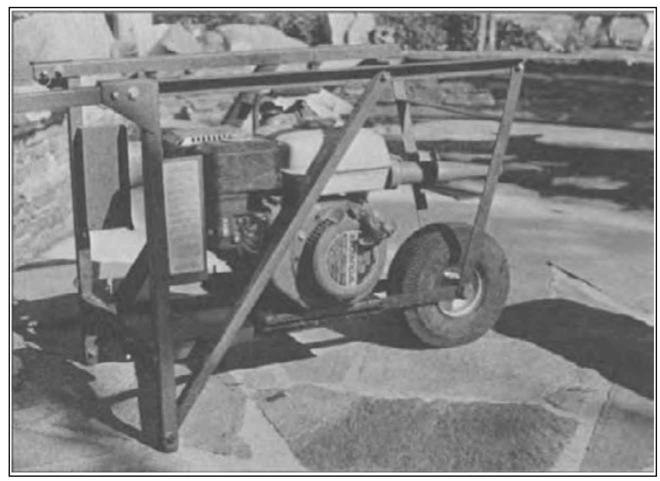

Figure 2–Portable fire pump used by a homeowner to protect his residence with pool water and Class A foam concentrate.

[1]An abbreviated version of this paper was presented at the Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems, February 15-17, 1994, Walnut Creek, California.

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The Legacy of Harold Biswell in Southern California: His Teaching Influence on the Use of Prescribed Fire[1]

Walter L. Graves[2] **Gary Reece [3]**

Historical accounts from early Spanish explorers who came to California looking for gold indicate that often they saw many columns of smoke rising from distant mountains. Little did these explorers know that what they were witnessing was a time-tested demonstration of natural lightning fires and/or "controlled burning," a technique practiced by Native Americans to prevent wildfires in the area's wildlands. Today we know this early fire ecology philosophy helped shape California's ecological history.

But in the years that followed the Spanish explorers, controlled burning by new migrations of settlers colonizing the West was thought to be destructive to our wildlands until a modern-day pioneer in fire ecology training came along. That man was Harold Biswell. His teaching and training activities in fire ecology, especially in southern California's San Diego County, during the 1970's and 80's continue to influence today's ecologist working to restore fire to the forests, chaparral, and grasslands in this region. Biswell was able to "transcend" the barrier between scientist and classroom. His "hands-on" concept of training and applying prescribed fire techniques is considered by many observers to be a unique approach to California's wildlands management.

Harold brought his wisdom and experience to southern California during the middle 1970's, when fire suppression philosophy and policy had become entrenched in government and public agencies responsible for wildlands fire control. Agency leaders were convinced that prescribed fire was of no value in chaparral and forest vegetation management. They believed it would adversely affect too many people and increase the threat of liability. In fact, during this period, the idea of prescribed fire technology and training was practically non-existent. But Harold Biswell, on the other hand, firmly believed in the importance of fire and its role in nature's plan. He based his beliefs on extensive research that examined not only the thousands of years of "natural fires" that had occurred in California, but also how Native Americans used fire in shaping the state's landscape. The message was long overdue when "Doc" Biswell began his educational and training programs in San Diego County nearly 20 years ago. His persistent and tireless efforts at promoting the restoration of fire to its evolutionary role in this region eventually influenced and encouraged state government leaders and others to lay aside the "myths" of fire exclusion in southern California.

Summary

We believe our videotape showing the following field day and workshop at the William Heise County Park in San Diego County in May 1983 illustrates Harold Biswell's teaching and training methodology in fire ecology and the importance of restoring (controlled) fire to our wildlands. Truly, California's history was born of fire, and this video captures Professor Harold Biswell's teaching emphasis on fire as a natural component of wildland ecosystems, Native Americans' use of fire in wildland ecosystems, smoke management, the importance of prescribed fire in fire management, the importance of training in fire management, and the education of the public about fire's role in ecosystem management.

Acknowledgments

We thank the Cooperative Extension Visual Media staff at the University of California, Davis–Harry Stoble, Steven Lock, and Robert Singleton–for helping us, with extreme patience, to produce this video. We especially appreciate the willingness of Visual Media's Coordinator, Rosalind Rickard, to allow these video production specialists to participate in this venture. We also want to applaud San Diego County's Department of Parks and Recreation for their courage in implementing a prescribed fire program at a time in our history when this concept was not considered popular.

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[1]An abbreviated version of this paper was presented at the Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems, February 15-17, 1994, Walnut Creek, California.

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Helping Wildland-Urban Interface Residents Reduce Wildfire Hazards[1]

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Abstract: Researchers in Michigan are designing and supporting studies to facilitate the identification of fire hazards on homesites in the wildland-urban interface, to elicit homeowners' perceptions of the wildfire risk where they live, and to assess the values that residents in fire-prone ecosystems place on reducing wildfire risk. A better understanding of the attitudes and values of interface residents will aid prevention specialists in targeting programs to help these residents mitigate wildfire hazards and reduce potential losses on their properties.

To help homeowners in the wildland-urban interface improve the chance that their homes will survive a wildfire, prevention specialists need to understand the many and varied reasons why homeowners choose to live where they do. They need to know which wildfire hazards are present on the homeowners' property that would increase losses to wildland fire. They also need to assess the homeowners' perception of wildfire risk (the probability that a wildfire will threaten their property).

Typically, prevention programs have been focused on the segment of the wildland-urban interface population that is most aware of wildfire risk and is most willing to remove or mitigate hazards on their property to reduce risk of property damage. A better understanding of risk perception and attitudes toward hazard reduction could help prevention specialists assess the understanding, values, and needs of all homeowners residing in the wildland-urban interface.

Morgan (1993) asserts that "the public can be very sensible about risk when companies, regulators, and other institutions give it the opportunity." He further states that risk communication is simple: "Learn what people already believe, tailor the communication to this knowledge and to the decisions people face and then subject the resulting message to careful empirical evaluation."

The USDA Forest Service's Atmospheric and Socioeconomic Relationships with Wildland Fire Work Unit, North Central Forest Experiment Station, is supporting cooperative research at Michigan State University (Fried 1993) that will increase the knowledge of homeowners' perceptions of wildfire risk and will assess the values of residents in fire-prone ecosystems about reducing risk. The unit is also developing studies to address the relationship between awareness of fire risk and hazard reduction activities among wildland-urban interface homeowners. As part of this research, four categories of these homeowners will be identified, on the basis of their hazard assessment rating and wildfire risk awareness:

- Low hazard rating and Aware of fire risk (L/A)
- Low hazard rating and Unaware of fire risk (L/U)
- High hazard rating and Aware of fire risk (H/A)
- High hazard rating and Unaware of fire risk (H/U)

Conceptual Approaches

The success of these studies will depend on conducting personal interviews. In addition to demographic questions (Bureau of the Census-type questions), open-ended questions will be designed to ascertain the homeowners' perception of wildfire risk around their homes, such as:

- How long have you lived at your current residence?
- If a fire occurred, how would firefighters locate your property?
- Have you experienced a wildfire at or near your home?
- Before that fire, were you concerned that a wildfire might occur?
- How often do wildfires occur in your neighborhood?
- If your home burned down tomorrow, what would you miss most?

Using a "wildfire hazard rating form" (Great Lakes Forest Fire Compact 1992), the interviewer and homeowner could rate site hazards (e.g., surrounding trees, type of ground cover, fuel storage), structural hazards (roofing materials, decks, and overhangs), and existing hazard reduction (trees pruned, leaves raked, roof cleaned outbuildings hazard-free). A "property hazard value" could be calculated by adding the total site hazard to the total structural hazard and subtracting the total hazard reduction.

In conjunction with these studies, geographic information system (GIS) databases could be built and maintained to store: (1) the information obtained during the interviews, (2) the owner's perception of risk, and (3) the "property hazard value." This information would facilitate queries like "how many" and "location of" the homesites with a given property hazard, owner risk-perception strata, or a combination of attributes. A GIS would also support tests for differences in demographic and site characteristics between homesites with low/high hazard ratings and homeowners with low/high risk awareness.

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Anticipated Benefits

Depending on how the database is sorted and analyzed, researchers can obtain a variety of information ranging from whether fire hazards are associated with income to the number of homeowners in each of the identified categories. Results can aid the wildfire prevention community's understanding of the knowledge, attitudes, and needs of homeowners who reside in the wildland-urban interface. Prevention specialists can use this information to select specific prevention programs for specific groups of homeowners and provide policymakers with information that can help them in developing cost-efficient programs to reduce the risks associated with fire in wildland-urban interfaces.

Acknowledgments

We thank Donald Johnson, fire prevention specialist at the Michigan Department of Natural Resources, Forest Management Division, Lansing, Michigan, for providing background information about wildfire hazard rating.

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Mt. Diablo Park: The Role of Fire in a Controversy about Cattle Grazing at the Urban Fringe[1]

Lynn Huntsinger Jeremy Fried Lita Buttolph[2]

Mt. Diablo State Park is in rapidly urbanizing Central Contra Costa County, a few miles inland from the eastern San Francisco Bay. The Park encompasses 18,000 acres of mountainous and rolling oak woodlands, chaparral, and grasslands, increasingly surrounded by San Francisco Bay Area suburbs. Easily accessible to millions of nearby urban dwellers, Mt. Diablo is among the most frequented of the California State Park System's 300 units, with more than 500,000 visits annually. The 1989 Park General Plan set goals for the park that included managing to restore natural processes. The Plan called for removal of livestock grazing from most of the park. Controversy over the elimination of grazing was of surprising vehemence and has lasted years. As a result, the General Plan process consumed more State Park time and resources than any previous Plan—even though this was not the first time grazing was phased out of a State Park.

Livestock grazing has been a component of the Mt. Diablo landscape since about 1834, when the mountain's slopes were part of a Mexican land grant. Founded in 1921, the Park has expanded from its original few hundred acres. In 1979, 2,000 acres of Mt. Diablo Ranch were sold and 281 acres donated to the State Park System by the owner, Angel Kerley. In exchange, a 10-year grazing lease was signed, but participants in the controversy disagreed about the nature of the lease. Some argued that the intention was for grazing to continue in perpetuity as an exhibit of ranching for local residents, while grazing opponents contended that there is no written evidence supporting this claim. During the last decade, Mt. Diablo Ranch, now a small in-holding, leased about 7,500 of the Park's acres for grazing. The 1989 Park General Plan decision was to not renew the lease, but to instead graze a few hundred acres for interpretive purposes.

Ecologically and socially, the grazing controversy echoed those on Federal lands. Plan proponents pointed to the "scientific evidence" that grazing benefits the environment. For example, grazing proponents argued that cattle refill the ecological niche left vacant by the absence of native tule elk and pronghorn antelope. Opponents argued that livestock grazing is significantly different in distribution and diet, injuring native plants and encouraging the spread of non-native weeds. But the Park's location on the urban fringe introduced a third, less typical viewpoint into the argument: local residents who believed that cattle grazing reduced the threat of wildfire.

The Cow as Symbol

This public lands grazing controversy had all the usual players: a remnant rural community for whom the cow symbolized "wise use" of natural resources to improve human life, and grazing opponents, for whom the cow symbolized human exploitation and abuse of natural resources. A new element was added because of the Park's suburban-fringe locale: a suburban public concerned about the hazard of wildland fires spreading to nearby residences. As a result, active participants in the Mt. Diablo debate included owners of high-priced homes near the Park. This wealthy, well-educated group strongly supported continued grazing in the Park and had the support of many local business interests.

Left ungrazed, the annual grasses of Mt. Diablo's slopes often reach 5 feet tall. Tinder-dry in summer and fall, they pose a considerable fire hazard. In Mediterranean climate zones worldwide, wildfire is a normal part of ecosystem function, as it is at Mt. Diablo. Grazing advocates, including some local Fire Chiefs, believe that grazing reduces fire hazard by removing biomass, and perhaps more importantly, preventing brush encroachment into grasslands. Opponents of grazing believe that only overgrazing reduces fire hazard, and believe that prescribed burning, mowing, and other techniques should be used instead of grazing. Unfortunately, in rapidly growing Contra Costa County, increasing development of wildlands and air quality restrictions can make extensive vegetation management practices, such as prescribed burning, costly and sometimes controversial. Letters from a local homeowner's association, for example, complained of unsightly blackened earth after a burn.

An Urban Fringe Controversy

The wildfire threat lent unusual power and financing to the pro-grazing side of the issue, contrary to the usual pattern of an "anti-grazing" block composed of people without rural roots. With homes near the Park commonly priced at more than $300,000, residents pay a premium for living near

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nature. They expect nature to be a "good neighbor." This expectation affects their view of land management policy and practice. In some places, urban residents dislike living near grazing operations. Livestock owners complain about trespass problems and depredation by pet dogs. At Mt. Diablo, a vocal portion of the local residents believed that the benefits of fire hazard reduction outweighed any inconvenience caused by the proximity of cattle. The livestock owner allied himself with these interests, and the controversy became a divisive and drawn-out one.

Suburbanites often move to the suburbs to escape urban dangers, and to make a long-term, secure investment in a home. For many in this controversy, the cow symbolizes a safe relationship with nature. By consuming flammable biomass, the cow seems to make the mountain a less capricious neighbor. This vision of the Park as a good neighbor makes restoration of natural processes difficult, particularly when one of the most important natural processes at Mt. Diablo is fire. Allowing development to border parks in which the goal is to restore natural processes makes achieving that goal nearly impossible. Ranch lands might be a valuable buffer between urban/suburban areas and protected or preserved natural systems. Ranches can provide an income to private landowners, yet connect preserved areas for wildlife and buffer developed areas from wildfire, prescribed burning, and other management activities. At the same time, they may buffer preserved areas from pets, vandals, and other intensive human impacts. Unfortunately, although those concerned with the protection of wildland systems and restoration of natural processes are distracted by their extremely polarized view of that ubiquitous rural resident, the cow, the prospects of achieving effective conservation of natural systems have become ever more remote because of urban sprawl.

Fire in a Tropical Savanna—a Double-Edged Sword[1]

Andrea L. Koonce, Timothy E. Paysen, and Bonni M. Corcoran[2]

Since the early 1960's, Caribbean pine (*Pinus caribaea var. hondurensis*) has been used for reforestation in northeastern Nicaragua. Caribbean pine is a species that grows naturally in the area, but its occurrence has increased because of its use, almost exclusively, as a reforestation species. It is thought to rely on the introduction of fire to successfully regenerate in tropical broadleaf zones (Perry 1991). Stands in northeastern Nicaragua, however, have been subject to an intolerably high fire frequency in recent years. In the area under study, 90 percent of the pine stands burn every year (*fig. 1*). Whether resource managers can turn around a self-perpetuating, downward spiral in resource production is an issue of critical importance for future rural economic development in the Miskito region. The current pathological fire frequency in the Caribbean pine savannas results from a combination of high levels of fire risk from human sources, and extremely flammable savanna fuels that thrive on fire. These pines are highly resistant to fire and are rarely killed, although they suffer severe setbacks in wood production and vigor for a number of years after a fire (*fig. 2*). The severe fire regime of the last 10 years has reduced the volume increment for the pines to 60 percent of its potential (Koonce and others 1993). Even if the introduction of fire into Caribbean pine stands is necessary, the stands of the Miskito Coast region of Nicaragua are examples of "too much, too often." Current and planned research in the region has the general goal of determining fire regimes that will optimize the vitality of northeastern Nicaragua's natural resources. Current studies are geared toward mitigation of unwanted fire effects, and understanding stand dynamics under the current fire regime.

Figure 1–Area under study in northeastern Nicaragua. The boggy lowlands of the Miskito coast region are predominately covered with Caribbean pine savannas.

Figure 2–A typical stand of Caribbean pine in the study area. The understory sedges are highly flammable.

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People—Fire Managers Must Talk With Them[1]

Arthur W. Magill[2]

Abstract: Fire managers know the wildland-urban interface fire problem is a people problem, but recognizing and addressing it are not the same. Managers have repeatedly stressed the need to avoid building with flammable materials and landscaping with fire-prone vegetation. Yet, residents continually fail to heed their warnings. Apparently, people not only respond poorly to warnings but tend to be oblivious to events that disastrously influence their property and lives. Also, the building trades build to satisfy people's desires, community plans do not address the interface fire issue, and governments have been unwilling to enact ordinances that control construction. Above all, fire managers would rather "talk" about public involvement than be immersed in it. These barriers may be removed, if fire managers overcome their reluctance to public involvement and become leaders in two-way communication with the people they wish to influence. These goals may be achieved if fire managers will seek training in the social sciences that emphasizes interpersonal relations, multicultural relations, and communication strategies.

Fire managers know the wildland-urban interface fire problem is a people problem, but recognizing the problem and addressing it in ways that are apt to cause interface residents to change their behavior are two different things. Fire managers recommend to people who move into the wildland-urban interface that they build fire-safe homes and protect them with defensible space. Yet, they are continually frustrated by residents who apparently do not hear or heed their warnings and recommendations to fireproof their homes and yards. Why, when taking action to protect their home from a wildfire seems obvious, do a majority of people fail to comply with fire-safe procedures?

Difficulties in Communication

Managers are quite comfortable dealing with "things," such as equipment, planning strategies, and fire behavior, but they gladly will let somebody else deal with people. Yet, the interface fire problem mandates that managers deal with people, like it or not. So, fire prevention managers need to become directly involved with their intended audience and to emphasize that building fire-safe communities can be profitable for business as well as environmentally pleasing to residents. However, accomplishing the task will require that managers reduce their concern with the technical and functional aspects of interface fires and become personally involved in two-way communication with homeowners, business people, and community leaders.

Communicating with homeowners is not easy, because people not only tend to respond poorly to warnings but tend to be oblivious to events that can have a disastrous influence on their property and lives. People tend to have varying awareness of environmental hazards. They tend to believe that various events "can't happen to them" whereas others' behavior demonstrates coping with or denial of hazardous events.

People in the building trades are aware that people want nice homes in attractive locations, so they have constructed attractive homes in the urban-wildland interface—homes that satisfy the locational, architectural, and landscape dreams of potential buyers, but contribute to the interface fire problem. If fire managers are to achieve their goals, they must confront and convince home building professionals to use fire-safe materials and designs.

Community plans frequently do not address the interface fire issue, and local governments have been unable or unwilling to enact ordinances that control development and construction. The unwillingness of governments to enact fire legislation may be related to an avoidance by politicians to be associated with actions that may be viewed unfavorably by their constituency (Sampson 1991). Regardless, fire managers must contact and encourage planners, local officials, and legislators to develop effective zoning ordinances.

In addition, managers should work with insurance companies to develop policy incentives that support local plans and ordinances. Overall, premiums for homes built in fire prone areas should reflect the higher costs associated with the greater risks, but they might be somewhat reduced for those homeowners who adapt to fire-safe road designs, architectural designs, and building materials.

Manager attitudes also bear on the communication problem as a consequence of their preference for working with "things" rather than people. They tend to "talk" more about public involvement rather than immersing themselves in it. For the most part, evidence of this preference by managers is rather subtle and is depicted by actual behavior as contrasted with professed behavior.

Recommendations and Conclusions

People—whether homeowners, design and construction professionals, or public officials—may be enticed to participate in fire safety programs provided they are given

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clear messages, presented by credible individuals who specify necessary actions, and provided the messages are reinforced locally. Fire managers should be considered the credible authorities on interface wildfires. They are especially effective as authorities if they have established themselves in a community through direct involvement with public education and involvement programs, and by soliciting the help of community leaders through dialogue to fortify the meaning and importance of their messages. The factors proven effective for warning of imminent hazards suggest that warnings be clear, specific for the desired response, derived from a credible source, reinforced locally, and conveyed by a positive message on prime-time television.

Fire managers, like other resource professionals, tend to be disinclined to initiate social interaction and to avoid situations involving abstract concepts and alternative solutions. The barriers may be removed, however, if fire managers overcome their reluctance to be directly involved with citizen involvement programs and establish two-way communication with the people they wish to influence. These goals may be achieved if fire managers pursue continuing education in the social sciences that emphasizes interpersonal and multicultural relations, and communication strategies.

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The Effects of Forest Fire Smoke on Firefighters[1]

Richard J. Mangan[2]

Abstract: Each fire season, 20,000 to 30,000 firefighters are engaged in suppressing wildfires and conducting prescribed burns on federal lands, and many more are employed in fire suppression on State and private lands. Studies of firefighter exposure to smoke and carbon monoxide indicated only occasional exposure until the 1987-1988 fire seasons in the West. During the 1988 Yellowstone fires, 12,000 respiratory problems were reported to medical personnel. To address this problem, the National Wildfire Coordinating Group (NWCG) assigned the USDA Forest Service's Missoula Technology and Development Center (MTDC) the responsibility to coordinate the national effort looking at the health effects of smoke on wildland firefighters. An interagency Technical Panel has been formed to provide direction and set priorities, and semi-annual newsletters ("Health Hazards of Smoke") are distributed to more than 7,000 firefighters nationally and internationally.

Each year, tens of thousands of wildland firefighters are involved in wildfire suppression and prescribed burning on millions of acres in the United States. For many years, the effects of exposure to smoke and carbon monoxide has been a minor concern, but has never emerged as a high priority. But, in 1987 and 1988, serious smoke inversions lasting many days and weeks caused significant respiratory problems in large numbers of wildland firefighters.

In 1989, the National Wildfire Coordinating Group (NWCG) assigned the USDA Forest Service's Missoula Technology and Development Center to coordinate the national effort and serve as the focal point for ongoing and future studies on the effects of wildland fire smoke on firefighters.

Study Areas

At a 1989 workshop in San Diego sponsored by NWCG and Johns Hopkins University, participants representing firefighters, union leaders, fire management specialists, occupational medicine, toxicology, industrial hygiene, fire chemistry, and protective equipment identified eight major areas of study that would encompass the concerns about the health effects of smoke:

- Retrospective Cohort Mortality Study—to determine if the long-range health of a firefighter is adversely affected as a result of past exposures to smoke;
- Prospective Injury and Illness Study—to develop a current system of data collection regarding wildland firefighter injury and illness to prospectively assess the role of smoke in the etiology of acute and long-term injury and illness;
- Chronic Pulmonary Function Study—to determine if wildland firefighters experience a chronic, accelerated loss of lung function during multiple fire seasons;
- Integrated Field Study—to establish a mobile team of industrial hygienists, wildland fire experts and occupational medicine specialists to conduct an intensive, integrated 3-year field study;
- Combustion Product Characterization and Toxicity Study—to develop sampling techniques, study combustion conditions and test diverse fuel conditions;
- Expanded Field Exposure Study—to provide firefighters with efficient methods for monitoring exposure and detecting cumulative effects;
- Integrated Risk Assessment—to assess the risk of exposure among firefighters;
- Risk Management—to develop an interactive program for use by fire management personnel to select risk management options based upon local conditions.

Completed Studies

As of this time, completed studies of breathing zone air samples collected from wildland firefighters and prescribed burners indicated some potential for hazardous exposure (respirable particulates, carbon monoxide, formaldehyde, acrolein). While these exposures have occasionally exceeded short-term exposure limits, very few cases have approached or exceeded allowable time-weighted averages. Smoke exposure from wildfires is not considered immediately dangerous to life and health.

Studies on the respiratory effects of smoke exposure on wildland firefighters indicate that exposure during a fire season may result in small changes in lung function. The health implications of short-term exposure and the potential health effects of long-term exposures have not been quantified.

Laboratory and field studies of respiratory protective devices have been conducted. Laboratory studies have focused on the effects of air-purifying respirators on work performance

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and on ways to predict the ability of firefighters to work while wearing a respirator. Field studies have included a survey to determine the field use of respirators, other methods of risk management, and field trial to evaluate a wide range of respirators in actual working conditions.

Current Studies

Current projects under the NWCG study include continued efforts to characterize the hazards of smoke, and to determine the health effects of repeated exposures; laboratory studies of the use of respirators and their effects on upper body work performance; field trials of existing and prototype respirators, smoke monitoring devices, medical evaluation and surveillance; and risk management strategies.

Acknowledgments

Brian J. Sharkey, Project Leader at Missoula Technology and Development Center (MTDC) and Professor of Human Physiology at the University of Montana, has been primarily responsible for initiating and guiding the "Health Hazards of Smoke" effort sponsored by the National Wildfire Coordinating Group (NWCG).

Burning in Arizona's Giant Cactus Community[1]

Marcia G. Narog[2] Andrea L. Koonce[3] Ruth C. Wilson[4] Bonni M. Corcoran[2]

Abstract: Giant saguaro cacti (*Carnegiea gigantea*) and associated vegetation are being burned by numerous wildfires, especially in areas of high public use. Specific fire effects on affected plant species and ecosystem resilence need to be defined, and management techniques for restoration of burned areas need to be developed. A research effort was initiated at the Saguaro Natural Scenic Area, Tonto National Forest, Arizona to determine how fire impacts saguaro community structure and species composition; to monitor fire ignition and spread patterns; and to analyze saguaro survival, vitality and abundance, and genome variabilty. Results from this study should improve our understanding of fire in the saguaro community and facilitate implementation of a pro-active fire management program.

Saguaro cacti (*Carnegiea gigantea*) and associated vegetation attract national and international tourists to the Sonoran desert in Arizona. Saguaros are an integral component of the biodiversity of both flora and fauna in this desert. Unfortunately, numerous wildfires concentrated in areas of high public use are destroying the saguaro and severely degrading many popular vistas, especially along the Saguaro Natural Scenic Area, Tonto National Forest, Arizona.

Fire History

Although a historical fire regime for this vegetation type is not presently known, natural fires have probably not been a major selecting force for much of the vegetation in the Sonoran desert. However, anthropogenic impacts include the introduction and expansion of alien plant species, especially grasses. Their growth has been accompanied by an increase in fire frequency, intensity, and extent. This change in fire regime may now threaten many non-fire adapted species. Of particular concern is the tropically evolved saguaro.

In many locations on the Tonto National Forest, the combination of herbaceous and shrub layers, including the many introduced species, form nearly contiguous and highly flammable fuels in the saguaros' range. Increased growth is especially common during years with heavy precipitation. On the Tonto National Forest, precipitation averages 7.66 inches. Rainfall was recorded at 14.24 inches and 13.34 inches for 1992 and 1993 respectively. In 1993, after these 2 years of above normal rainfall, 104 fires (twice the yearly average) were recorded on the Mesa Ranger District, Tonto National Forest. These fires included both accidental and deliberate fire ignitions. One arsonist is believed to have been responsible for setting multiple fires that burned hundreds of acres. These acres included prime tourist attraction areas such as the Desert Vista View Observation Point on the popular Bee-Line Highway.

Saguaro and Fire

Saguaro can grow to heights of 18 m, weigh more than 2 tons, and is estimated to live about 200 years (Holden and Farrell 1991). Wildfire may kill significant numbers of cacti and succulents that characterize the saguaro communities (Thomas 1991, Rogers 1985, Mclaughlin and Bowers 1982). Specific fire effects on plant species and ecosystem resilience have yet to be defined (Ahlstrand 1982).

Fire affects saguaro reproduction and survival. Generally, only one seed in 1,000 may germinate; less than 1 percent of these will survive more than 6 weeks (Holden and Farrell 1991). Fire may contribute to an increase in juvenile mortality. Saguaro growth is slow, especially during the first few years. In nature, approximate size/age relationships for saguaro are 1 cm in height after 5 years, 1 m after 30 yr, and 10 m after 100 years (Holden and Farrell 1991). Fire injury may also lead to increased mortality of mature saguaro (Thomas 1991).

Nurse plants, such as the palo verde, are reported to be necessary for saguaro reproduction and survival (Gibson and Nobel 1986, McAuliffe 1984, Vandermeer 1980). Ironically, nurse plants may contribute to higher saguaro mortality from fire because of increased local fuel loading.

Fire Management

Rogers (1986) compared fire occurrence in desert and nondesert vegetation on the Tonto National Forest from 1955 to 1983; desert fires were fewer, larger, and unsuppressed, compared to the more numerous but smaller nondesert fires. A recent update of the fire frequency and acreage burned during the last recorded decade (1983 to 1992) showed similar trends (*figs. 1* and *2*). Ninety percent

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of this desert vegetation class is composed of the saguaro plant association. Cave and Patton (1984) evaluated wildfire versus controlled burning in the Sonoran desert. They provide evidence that fire alters species composition and dramatically reduces cacti presence. They concluded "that any efforts to use prescribed burning should remain experimental until a long-term data base exists on which to make more reliable predictions." Apparently, hundreds of fire ignitions occur and thousands of acres are burned in saguaro habitats. Although this fire problem continues, this vegetation type still has low priority for fire suppression resources, such as equipment, personnel, and dollars.

Current Research

To justify greater expenditures of fire suppression resources on the saguaro community, the Tonto National Forest requested that the Prescribed Fire Research Unit of the Pacific Southwest Research Station develop strategies that would be effective for the Tonto's fire management program. In order to evaluate alternatives, some basic research must first be conducted.

Our study area is located in the northeast section of the saguaro's range on the Mesa Ranger District, Tonto National Forest. For our preliminary investigations, we have defined four major objectives: examining fire effects on saguaro community structure and composition, including different plant strategies such as germination or resprouting after fire; monitoring fire ignition and spread patterns during prescribed burns; analyzing the impact of fire on saguaro survival, vitality and abundance; and studying fire effects on saguaro genome variability. We are currently designing study parameters and will be implementing a 5-year study evaluating prescription burning and areas previously burned by wildfire in the saguaro community.

Summary

We believe that fire suppression strategies need to be implemented to limit fire spread with minimal habitat disturbance. Currently, we need more information on factors that contribute to flammability and fire damage in this ecosystem. After our objectives in this study are met, management strategies and techniques need to be developed for aggressive restoration of fire degraded areas.

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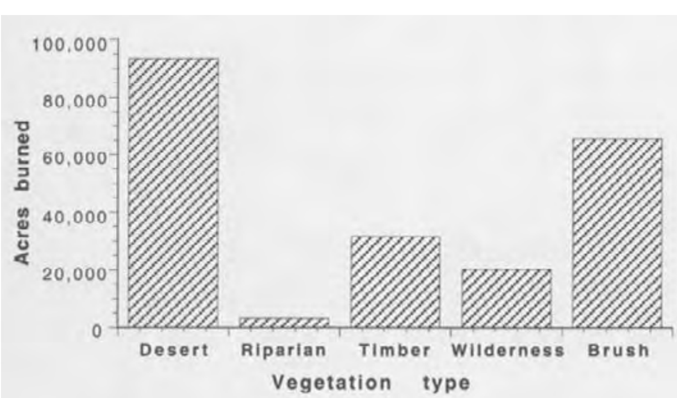

Figure 1–Total acreage burned on the Tonto National Forest, Arizona from 1973 to 1992.

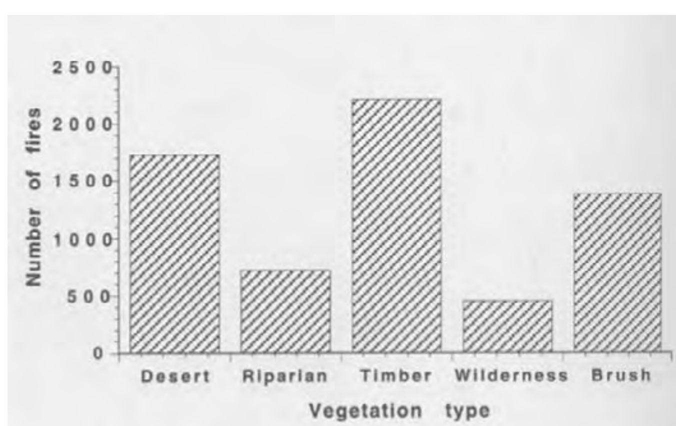

Figure 2–Total number of fires recorded on the Tonto National Forest, Arizona from 1973 to 1992.

A Computer Program for Evaluating Prescribed Fire Costs[1]

Philip N. Omi Douglas B. Rideout Stephen J. Botti[2]

Abstract: How much should prescribed fires cost? What are reasonable cost estimates for conducting a burn, in terms of site preparation, ignition, and containment? How might a manager ascertain if proposed costs are reasonable? Similar questions arise for any prescribed fire program that involves a large geographic area. A computer program was developed to answer such questions, based on regression analysis of historical records within regions of the USDI National Park Service (NPS). Although restricted to the NPS, we discovered a cost structure for fuel treatments that should apply generally. Cost estimates were found to be sensitive to management objectives, geographic region, project size, complexity of burn, and potential for escape. The computer program is written in PASCAL and designed to address the entire range of environmental, ecological, and economic factors considered in the NPS prescribed fire data base. This information is useful to land managers, but also should be of general interest for comparing fire with other alternatives for managing fuels in wildland and urban interface areas.

The USDI National Park Service (NPS) Hazard Fuel System was developed to aid prescribed fire management within the agency, particularly with respect to budgeting and tracking costs for reducing fuel combustibles on NPS lands. Before the development of this system, the NPS (or any agency) did not have a standardized procedure for assessing the accuracy of cost requests from field units for proposed prescribed fire projects.

This paper highlights one approach to assess the range of reasonable cost requests; this method can be applied regardless of public agency jurisdiction, geographic location and management situation.

Objective

Our goal was to develop cost target zones (i.e., ranges of reasonable costs) for fuel treatment projects, based on important predictors of cost variability. The computer program was designed to display these zones in an interactive format.

Methods

We obtained electronic data files maintained by the NPS Branch of Fire Management for recent and future hazard fuels projects submitted by park units. The Hazard Fuels data set contains specific information on project size, fuel model, project type, ranking score, administrative or legislative mandate, complexity score, and descriptive remarks. Hazard fuel projects are meant to lower the impacts of wildland ignitions that might originate in wildland vegetation types and pose a threat to public safety, structures, improvements, or cultural and natural resources.

Based on historical funding requests from field units, cost target zones were constructed for Hazard Fuel projects (Omi and others 1994) using standard regression procedures. The regression equation and 95 percent confidence interval were used in a computer program (written in PASCAL) to display the range of acceptable costs for Hazard Fuel projects. The program queries the user about relevant inputs related to the entire range of environmental, ecological, and economic factors considered in the NPS data base. This information is useful to land managers, but also should be of general interest for comparing fire with other alternatives for managing fuels in wildland and urban interface areas.

Results

Regression coefficients were derived from a step-wise procedure in which all variables in the Hazard Fuels data set were initially considered in terms of their contribution to explaining variation in cost requests. The regression coefficients explained 91 percent of the variation in (log-transformed) cost. All coefficients were significant ($p < 0.01$), as explained in Omi and others (1994).

A typical screen from the computer program (RXCOST) was developed from our regression analysis (*fig. 1*) (Stone and others 1992). Upon entering the program, a user is queried about size of project (ac), the National Fire Danger Rating System (NFDRS) fuel model, management type (fire, mechanical, biological, or chemical treatment), natural resource rank (1 to 9), and potential for escape (1 to 9). The cost per acre target and range correspond, respectively, to the regression prediction and upper (lower) 95 percent confidence limits. The user may also request a wider or narrower target zone than the 95 percent confidence interval by specifying a range greater or less than one. Future cost requests outside the range of acceptability are not necessarily invalid; rather, such requests may indicate the need for additional rationale.

[1]An abbreviated version of this paper was presented at the Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems, February 15-17, 1994, Walnut Creek, California.

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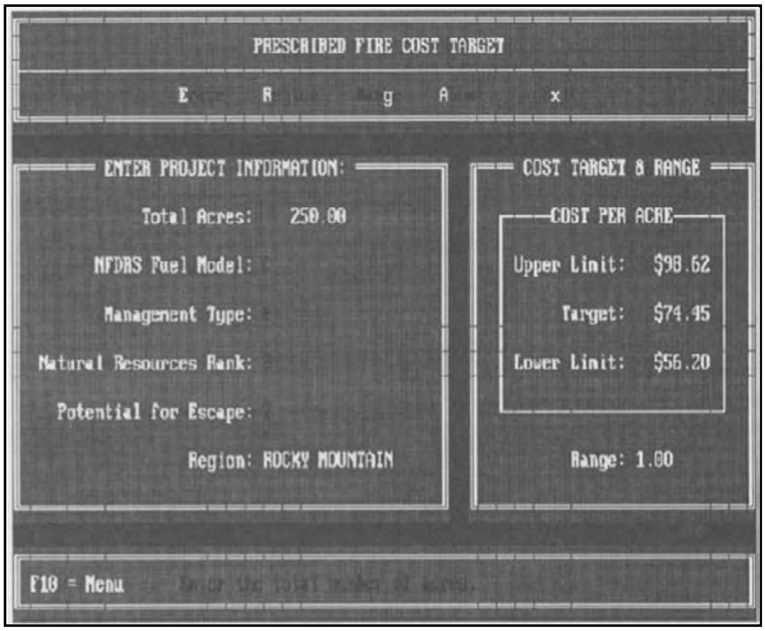

Figure 1–Representative screen from program RXCOST showing average (target) cost per acre of $74.45 for a 250-acre proposed prescribed burn (management type F) in NFDRS fuel model C, with natural resource rank 8 (high) and moderate potential for escape (7) in the Rocky Mountain region. The range specification of 1.00 uses the 95 percent confidence interval to set the upper and lower limit for the target. Proposed projects which exceed $98.62/acre or fall short of $56.20 (i.e., outside upper and lower limits) deserve additional scrutiny.

Conclusions

The cost target zones identified by the computer program RXCOST (Stone and others 1992) are those projects whose cost requests are either excessive or under-financed, that is, outside the range of historic acceptability. We believe the estimates from the computer program are applicable to a wide range of situations, including different geographic regions, fuel conditions, or other project descriptors.These cost ranges from the program should be considered as providing guidance for improved decision-making, but not as the sole criterion for assessing treatment cost. A cost request that falls outside the range of acceptability (based on the computer program) should not be rejected without further investigation. The resulting analysis might reveal that projected costs are justifiable because of extenuating circumstances associated with a proposed project, for example. Thus, the zones should be applied with the usual discretion and good judgment associated with crucial decisions.

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Potential Nitrogen Losses due to Fire from *Pinus halepensis* Stands in the Alicante Province (Southeastern Spain): Mineralomass Variability[1]

Antonio Pastor-Lopez **Joaquin Martin-Martin** [2]

Abstract: Potential nitrogen volatilization during fire was calculated for *Pinus halepensis* plantations. The stands located in the Alicante province (southeastern Spain) represent a range of site qualities and are more than 25 years old. Biomass and nitrogen content for fractions smaller than 1 centimeter in diameter and for the total were determined. A 70 percent volatilization of the nitrogen in the biomass represents a loss of 8.2 to 116.5 kilograms per hectare for stands with total aboveground biomass of 5.06 and 151.12 tons per hectare. The percentage of nitrogen lost from the total biomass is larger in sites of lower site quality.

The effects of fire regimes on the sustainablility of ecosystems constitute one of the main aspects to consider. Nitrogen is a fundamental element for soil productivity even in drought-prone ecosystems where water has a dominant role. Nitrogen outputs through volatilization during fire events is very significant. During this century large extensions in the Mediterranean Basin were planted with different conifers after fire or other perturbation events. In Spain, Aleppo pine (*Pinus halepensis*) was used in most of these plantations. The modification of the fire regime, with an increase in fire events, caused by the nature of these monocultures and human actions, has completely modified the temporal scale and potentiality of recovery in many areas. These factors are fundamental in the sustainability of the long-term productivity of these systems. This paper characterizes the nitrogen pool available in the biomass in stands more than 25 years old along a range of site qualities. It estimates the potential nitrogen lost by applying the trends of volatization shown in the literature. This paper is directed toward defining the magnitude of nitrogen lost in these stands as an indication of the amount that would need to be restored in order to avoid a reduction in its total pool and therefore productivity of these ecosystems.

Study Area and Methods

The study was conducted in Aleppo pine stands located in Alicante province. Alicante is located in the western coastal Mediterranean Basin in southeastern Spain (37º 50' to 38º 55' N and 1º 05' to 0º 10' E). The sites were selected out of a general survey for the province during 1985. A total of 120 stands were sampled in a range of age, climate, and site quality conditions. The age of the stands considered is representative of that of the plantations started during the national afforestation program for soil conservation purposes between 1945 and 1985. The silvicultural treatments that the stands have undergone include pruning of the lowest branch whorl 5 years after planting and a later pruning of 1 or 2 whorls in the following 10 years. The existing variability of the Aleppo pine stands in the Allicante province is representative of that in the Mediterranean Basin as to the range in climate between subhumid and semiarid Mediterranean conditions (Nahal 1981). From the 120 stands considered, 4 master stands were selected, along a site quality range, to elaborate equations describing destructive biomass sampling, as well as detailed nutrient contents analysis. Ten trees were cut down to obtain biomass equations in each one of the four stands selected. The stands were representative of the range of site qualities that can be commonly expected in the Alicante province (Pastor-Lopez 1992).

To determine the nitrogen pool that could be lost in a fire event, the biomass for four fractions was considered: leaves, shoots (stems holding leaves, always smaller than 1 centimeter in diameter), fine branches (stems not holding leaves and larger than 1 centimeter in diameter) and the rest of the aboveground structures. The first three constituted fraction I and the last fraction II. The reason for defining 1 centimeter in diameter as the limit is based on the statement by Wells and others (1979) that the plant stems remaining after a moderately intense burn or a severe fire are greater than 0.6 or 1.3 centimeters in diameter. All determinations of nitrogen contents were done by the Kjeldahl procedure.

To better define the limits of nitrogen available on a more extensive sample, 32 stands more than 25 years old were selected out of the above-mentioned sample of 120. Each fraction biomass for these 32 stands was determined by applying the equations from the master stands to the sample plot measurements obtained for every stand. Each stand was assigned a set of the four groups of biomass equations. The

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matching criterion was similarity in site index with one of the four master stands. Nitrogen content of leaf and shoot fractions was determined, using the Kjeldahl procedure, from a sample of 1-year-old leaves and shoots for each of the 32 stands. The nitrogen contents fine branch and fraction II were assigned by averaging from the master stands the different replicates analyzed by fraction (Pastor-Lopez 1992). Each stand was assigned the same master stand as for the biomass equations. Out of the 32 stands considered, those representing the limits of nitrogen accumulation on an age and site index spectrum are included in the following section.

Results and Discussion

The four stations where destructive biomass sampling was completed were also studied for nitrogen mineralomass as well as other nutrients (Pastor-Lopez 1992). The results obtained illustrate how nitrogen accumulated in different structures. *Table 1* gathers the information on the dendrometric and stand structure characteristics of these four master stands.

Nitrogen mineralomass and the percentage of it in the different structures included in the fraction smaller than 1 centimeter in diameter are included in *table 2*.

From the 32 stands considered for the more extensive and representative sample, 7 stands were selected as representative of the limits of variability for age and site index. *Table 3* includes the dendrometric characteristics of these stands.

Nitrogen contents for these stands and the potential maximum mineralomass available for fraction I and others are included in *table 4*. The percentage of the total above-ground nitrogen mineralomass, represented by the amount of nitrogen accumulated in fraction I, represents the potential maximum amount to be lost in a fire event. Nevertheless, there are different factors that influence this loss.

Woodmansee and Wallach (1981) indicated that two of the factors that determine the amounts of elements lost during a fire include the biomass and the elemental composition of the vegetation. This information has been shown already and would reflect a maximum to be lost; nevertheless, intensity and duration of the fire play a very important role in determining the limit. White and others (1973) determined that complete volatilization occurs at temperatures above 500 degrees Celsius and almost none below 200 degrees. Rundel (1981) pointed out with several examples the importance of the temperature of the fire in relation to the amount of nitrogen volatilization expected. The range given by him varies between 58 and 85 percent under laboratory conditions. Lobert and others (1990) give a value of 90 percent.

Bernard and Nimour (1993) determined, for *Pinus halepensis* in laboratory conditions, ignition temperatures between 235 and 330 degrees Celsius. They indicated that lignin, lipids, some or all the holocellulose and the ashes were the residues from combustion at these temperatures. On the other hand, they pointed out that volatization of the substances depended on the water content and chemical

Table 1—*Dendrometric characteristics of the four master stands*

Characteristics[1]	Stand codes 8601	6502	3702	1701
Age (years)	28	36	27	32
Density (trees/ha)	1550	1600	1682	1350
Site index (height in meters at 20 years)	4.8	3.2	1.4	1.5
Basal area (m^2/ha)[1]	34.86	23.61	3.45	9.77

[1]Measured at 0.5 m.

Table 2—*Nitrogen mineralomass and relative percentage by fractions*

Stands	8601	6502	3702	1701
Nitrogen mineralomass (kg/ha)				
Fraction I	161.4	61.4	14.9	30.0
Total	311.4	96.5	19.7	40.6
Percentage of total nitrogen mineralomass by fraction				
Leaves	28.83	38.71	45.23	47.92
Shoot[1]	8.26	5.44	6.30	7.87
Fine Branches[2]	14.74	19.49	23.95	17.99
Fraction II[3]	48.17	36.36	24.52	26.22

[1]"Shoot" refers to those holding leaves.
[2]"Fine branches" refers to stems with diameter smaller than one centimeter.
[3]Fraction II includes rest of the above-ground structures of the tree.

Table 3—*Dendrometric characteristics of sample stands.*

Stand	Age	Density	Site index[1]	Total Aboveground Biomass
	yr	*trees/ha*	*m*	*tons/ha*
191	25	2600	1.8	13.306
43	28	2700	0.6	5.060
211	39	2350	0.5	5.613
141	42	1289	2.7	38.554
551	42	1079	4.7	92.403
901	35	969	5.8	116.562
811	32	2720	5.4	151.120

[1]Site index (height in meters at 20 years).

composition of the structures burned, for which the phenological state had important consequences. No measurements had been done, in natural conditions, of the temperature reached during ignition for these stands, nor for Aleppo pine. The dense crown characteristic of the species and the low height (2 to 8 meters) due to limitations in soil productivity ensure that most fires in these stands will behave like crown fires. For the interval of 300 to 400 degrees Celsius the percentage of nitrogen volatilized represents 50 to 75 percent of the total amount in the biomass, according to White and others (1973). Rundel (1981) indicated losses of 70 percent for *Pinus*.

If we consider 70 percent as a compromise between the high levels obtained in the laboratory and the lower ones observed in natural conditions, the range of nitrogen lost for Aleppo pine in the plantations studied would be between 8.18 and 116.47 kilograms per hectare for stands with respective total aboveground biomass of 5.060 and 151.120 tons per hectare. Although not validated, this paper gives the first estimates on the potential losses of nitrogen in a broad range of site qualities. The frequent use of the species around the Mediterranean Sea and the new European economic community policy for afforestation of abandoned agricultural lands will increase the extension of these stands. The high incidence of fire along these areas, caused by arson or accidents, could be considered the most important source of atmospheric emissions in these areas. On the other hand, as Debano and others (1979) indicated, the total amount of nitrogen on an area basis is always reduced after a fire, in relation to the prefire status. The need to determine the agents that restore the original nitrogen levels and their rate is fundamental for maintaining the productivity of these sites. *Ulex parviflorus* is a typical leguminous evergreen species that responds with a prominent increase in cover after fire events. Its nitrogen-fixing capacity should be determined in order to define the magnitude and timing of its input. The magnitude and timing in the input of nitrogen fix that is mentioned in the previous sentence must define which are the potential management procedures to deal with *Ulex parviflorus*. The extended belief is that this *Ulex,* because of its high flammability and large accumulation of dead material, must be eliminated. This action could represent a depletion of the greatest input of nitrogen to the system during the growth periods following the fire.

The percentage of nitrogen lost from the total in the biomass is clearly larger in the sites with a lower site quality. These sites should show more efficient mechanisms to restore nitrogen or they will be much more susceptible to degradation by future fire events. In other words, under a similar fire perturbation regime, low-site-quality stands will be more susceptible to losses in long-term site productivity than other stands with higher site quality.

Table 4—*Nitrogen contents, mineralomass and percentage of nitrogen from aboveground total for plantations representing the limits of age and site index.*

Stand	Nitrogen content		Nitrogen mineralomass				
	Shoots	Leaves	Shoots	Leaves	Fraction I	Fraction II	Total N in Fraction I
	---------- *pct* ----------		------------------------- *kg/ha* -------------------------				*pct*
191	0.410	1.020	1.79	19.76	29.28	17.55	62.5
43	0.265	0.615	0.50	6.27	11.68	3.63	76.3
211	0.330	1.990	0.69	21.64	27.58	4.17	86.9
141	0.587	0.868	6.27	44.24	72.63	34.61	67.7
551	0.746	1.113	14.87	86.16	110.64	157.45	41.3
901	0.742	1.456	17.82	135.04	164.36	200.15	45.1
811	0.628	1.095	21.77	130.06	166.39	259.28	39.1

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Susceptibility to Potential Erosion after Fire in Mediterranean Ecosystems in the Alicante Province (Southeastern Spain)[1]

Antonio Pastor-Lopez Joaquin Martin-Martin[2]

Abstract: Postfire precipitation regimes are important to the dynamics of the physical and biological processes occurring after fire. From 1972 through 1991, 143 fire events of at least 100 hectares occurred in Alicante province, Spain; 42.5 percent of the area burned in August. The trends for total, pregrowth season, October, and September through November precipitation for 1 year after each fire are shown. Half of the burned areas received more than 349 (and up to 880) millimeters of rainfall before the growing season and between 44 and 325 millimeters during the first October after fire. Erosion events before the beginning of the growing season and spatial relocation of ash layer materials on a watershed basis are major factors expected to contribute to postfire erosion.

Fire has been an active agent in the evolution and shaping of the structure of vegetation in the Mediterranean Basin. Nevertheless, the increase in fire frequency by arson or management actions has modified disturbance regimes to a level that might exceed the resilience of the system.

Despite the difficulty of quantitatively linking precipitation and erosion, the frequency of erosion events has been clearly related to specific macroclimatic conditions. In the Alicante province in southeastern Spain, the highest erosion frequency has been observed in October. Fire may affect soil fertility via the export of large quantities of nutrients through debris flows and run-off. Identifying the rainfall regimes experienced by burned areas after a fire can help define the framework in which these ecosystems develop. This paper addresses the problem of susceptibility to erosion in postfire conditions.

Study Area and Methods

The province of Alicante is located in the western coastal Mediterranean Basin on the southeastern Iberian Peninsula (37º 50' to 38º 55' N and 1º 05'W to 0º 10' E), with 581,901 hectares and 140 municipalities. The province has an important wildfire problem. In 20 years (1972-1991), 62,074 hectares burned in 143 fires of at least 100 hectares each. This area represents 10.7 percent of the whole province and 26.7 percent of the naturally vegetated area. Sixty-eight municipalities were affected at least once (48.6 percent). For these municipalities, the area burned added up to 28.8 percent and 55.8 percent of their total and natural vegetation areas, respectively. Although information was not available on areas that suffered recurrent fires, it was evident that fire was an important perturbation in these ecosystems.

We studied fires 100 hectares or greater in area. Date of occurrence, area of extent, and location were used to characterize the fire regime. To define the precipitation regime, 15 climatological stations available from the area were used. The burned areas were assigned the climatological data from the closest station for the first year after fires, which is when the highest susceptibility to erosion occurs (Debano and others 1979), and we then evaluated four variables. First, total precipitation was examined for 1 year after the fire. In Mediterranean-type ecosystems in southern California, erosion during the first year can be as much as 35 times greater than normal (Wells 1982). Next we examined precipitation that had been measured between the fire and the beginning of the next growing season, which, unlike southern California, begins in March for most higher plants because of the cooler winters in the Alicante province. This information was used to evaluate both the possibility of high precipitation when the vegetation cover was minimal as well as the potential availability of water for plant regrowth and thus soil protection. We also evaluated precipitation during the first October after fire. Sanchez (1989) conducted a 5-year study in Alicante and found that 57 percent of the erosion events and 54 percent of the sediment accumulation occurred in October. And lastly, precipitation during the September-October-November period after the fire was examined because this season tends to have the greatest amount of precipitation, according to more than 30 years of observations collected by the network from the Centro Meteorologico de Levante.

Results and Discussion

During the 20-year period, two main peaks of the area burned (over 8,000 hectares per year), which were separated by 12 years with values below 4,000 hectares per year. The two maxima occurred in 1978 and 1990. On a monthly basis, 42.5 percent of the area burned in August, followed by 25.3, 15.1 and 10 percent in July, September and October respectively. The number of fires was 10 percent greater in September than in July, indicating larger fires in the latter. Fires did not occur in January and March, and no more than

[1]An abbreviated version of this paper was presented at the Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems, February 15-17, 1994, Walnut Creek, California.

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2.1 percent of the area burned in any other month. The median fire size was 225 hectares. Seventy-eight percent of the fires were smaller than 500 hectares and 8.4 percent were greater than 1,000 hectares. The largest fire was 6,800 hectares.

Total precipitation during the first year postfire ranged between 126 and 1,210 millimeters. Half of the fire areas received less than 523 millimeters and 25 percent received more than 775 millimeters. Most of the values in the lower quartile fell between 200 and 390 millimeters. This pattern is typical of the subhumid mediterranean climate of the area. The amount of rain falling between the fire and the start of the growing season (March) ranged between 6.4 and 880 millimeters with 75 percent of the fires receiving less than 478 millimeters. The upper limit of the lower quartile was 188 millimeters and 50 percent of the sites received more than 349 millimeters. The first October after a fire had precipitation totals between 0 and 325 millimeters, although 50 percent of the stands received less than 44 millimeters. Only 8 percent of the cases received no precipitation at all during this month, while just 5 percent received more than 200 millimeters. Fire events followed by zero precipitation did not occur during the September-October-November period, and just 5.6 percent received less than 50 millimeters. Although rainfall ranged between 9.6 and 761 millimeters, 75 percent of the cases had less than 210 millimeters and just 1.3 percent had more than 400 millimeters.

The amount of precipitation that fell before any vegetation covered the soils could be as high as the mean annual precipitation in the semiarid areas of the province. The rates of erosion during the pregrowth periods should be studied; if significant erosion occurs before plant growth begins, revegetation efforts would be ineffective because of phenological constraints. Some type of physical intervention would be the only way to reduce erosion. That 25 percent of the stands received more than 134 millimeters of rain in October should not be considered proof of high susceptibility to erosion—we found no evidence in the literature connecting higher precipitation with higher erosion. The erosion events recorded by Sanchez (1989) indicated that neither total precipitation nor maximum intensity explained the amount of sediment produced. A rainfall of 25 millimeters with a maximum intensity of 68 millimeters per hour produced 352.4 grams per square meter of sediment, while another event with a total of 45.4 millimeters and an intensity of 130 millimeters per hour produced 63.1 grams per square meter. This first postfire rainfall will determine the state and distribution of the ash layer. The importance of this layer due to the accumulation of nutrients is important for the microbial and plant postfire communities. The total nutrient status of the ecosystem could be largely modified depending on what happened with this layer. Movement of the ash layer by rainfall events should be studied to determine whether nutrients are actually lost from the system or simply relocated. The problem indicated by Debano and Dunn (1982)—that erosional losses of nutrients from on-site movement may differ considerably from those for the entire watershed—must be considered given the high amount of nutrients contained in the ash layer.

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Operational Fire/GIS Dilemmas—The Fire Report Form Example[1]

Lucy Anne Salazar[2] **Martha Shea Flattley**[3]

Operational applications of geographic information system (GIS) technology for fire management sometimes develop into dilemmas regarding data acquisition, compatibility, and accuracy. One major component of a Fire/GIS database is recorded fire history, such as the information contained in USDA Forest Service records collected since 1910. These fire report forms were revised approximately every decade and included different formats, entry items, naming conventions, and level of detail for maps (if maps were even included). To accommodate GIS needs, the challenge is to find, decipher, compare, and coalesce these fire data into a database that will be useful for incorporating into ecosystem management.

The Six Rivers National Forest was formed from the Shasta-Trinity, Klamath, and Siskiyou National Forests in 1947. After extensive searching, limited fire records have been found for the pre-1947 period. Fire summaries recorded general information such as origin date, fire size class, township, range and section, vegetation type, and general cause. Original fire report forms were found for portions of the Forest, and gaps in the data are obvious. For one Ranger District, fire history is recorded for over 80 years, in 12 different fire report forms. Fire atlases also exist for some Ranger Districts since 1936 and for others since 1910.

Differences in format and naming conventions exist among the eight decades of fire reporting. These differences need to be resolved so that the data, and issues such as ground truthing and ancillary information (e.g., weather records and narratives), can be incorporated into a GIS format.

Data Consistency

Forest management and activities have changed dramatically over the years; these changes are often also reflected in the fire report form entries. Representations of vegetation ignited or burned through by fires is one example of an entry item that has gone through several revisions. Entries for "character of cover" in the 1910's were very general, including rocks, brush, timber (needles), reproduction, and oak leaves. Descriptions in the early 1920's became more specific, splitting up cover types into timber, brush, ground cover under timber, and ground cover under brush. Later in the 1920's and throughout the 1930's the emphasis changed to entries of general categories, such as timber, brush, leaves, and needles. The 1940's through the 1970's focused on entries by species. The codes for the 1980's returned to more general cover descriptions (e.g., over-mature timber, long needle plantations) and included age groupings for slash categories.

The National Interagency Fire Management Integrated Database (NIFMID) is currently being developed as a corporate fire database. This GIS compatible database will allow fire data to be shared, analyzed, and integrated into ecosystem analysis and management. NIFMID includes Forest Service fire report form entries back to 1970. Pre-1970 fire report form entries also need to be brought into NIFMID to include in the analysis. NIFMID currently has 667 possible entries for the principal vegetation cover at or near the point of origin of a fire. This list should accommodate the vast majority of historic entries, but descriptions such as needles or leaves will have to be included as valid data.

Ground Truthing

During the early 1900's fire managers took great care in filling out fire report forms. This was reflected in the detail of their fire maps and the extent of their narratives. This detail has dramatically decreased so that, currently, a map is not even required for the fire report forms. In a GIS mode this can create problems, especially when the only locational data now recorded is the latitude and longitude of the fire's origin. Maps are part of the documentation for large fires, but they are often stored in boxes in warehouses that never become part of a map database. Perimeters have become of little consequence for fire reporting, while for ecosystem analysis they are of utmost importance.

Ground truthing of fires can help determine the conditions under which certain areas did or did not burn. This is important information for large area natural fuel treatments and prescribed natural fires. Technologies such as global positioning systems (GPS) allow for fire perimeters to be easily mapped, including islands and different intensities within the perimeter. Aerial photos can also sometimes be used as a substitute for ground truthing, but timing and quality of the aerial photos can have an effect on their usefulness.

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[1] An abbreviated version of this paper was presented at the Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems, February 15-17, 1994, Walnut Creek, California.

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Ancillary Data

Early fire report forms are filled with interesting anecdotes and narratives. For example, some provide descriptions of forest guards who would leave for fires with four men and travel 28 miles by horseback to battle a 500-acre fire. These early fires might appear to have become large because of a lack of sufficient resources. Monthly precipitation records exist for many weather stations in California back to 1880. By combining these data with fire occurrence records, we see that often times the large fall fires occurred after periods with below-normal summer rains or above-normal spring rains. Currently, these same weather patterns combined with unnaturally high fuel loadings and the urban wildland intermix could result in catastrophic fire events. Knowledge of Native American historical uses of the forest can also provide an important component in determining how the ecosystem evolved into its current state. Thus, fire report forms contain a wealth of knowledge to assist us in our objectives of determining and managing fire's natural role in the ecosystem.

Recommendations

To analyze fire's natural role in the ecosystem, fire records and maps must be found and preserved as a vital part of the history of each National Forest, community, and local ecosystem. We also need to resolve differences in fire report form entries, and develop a method to incorporate fire occurrence data into the analysis. And fire managers must encourage detailed narratives and mapping of fires, including the use of global positioning systems (GPS) technologies. These data can be incorporated in a GIS for analysis of fire's natural role in the environment.

Progression of the Oakland/Berkeley Hills "Tunnel Fire"[1]

David B. Sapsis[2] **Donald V. Pearman**[2] **Robert E. Martin**[2]

On the morning of October 20, 1991, a fire originated in the Oakland/Berkeley Hills from rekindling materials of a 2-hectare brushfire that had occurred the previous day. The ensuing "Tunnel Fire" resulted in the greatest modern-era loss of life and property on record for North American urban-interface fires: 25 people died, 2,475 dwelling units were completely destroyed, an additional 302 units were badly damaged. Losses have been estimated in excess of 1.7 billion dollars.

This paper describes the spatial dynamics of the "Tunnel Fire" and provides insights into the interaction of environmental factors contributing to the catastrophic behavior of the fire.

Methods

All available direct physical evidence (e.g., photography, video, communication transcripts) were systematically reviewed to ascertain the position of the fire and apparent mechanisms of spread. These data were then corroborated by interviews with witnesses and public service personnel, as well as reviews of agency incident reports documenting the fire. Particular attention was placed on cross-referencing known timed events (e.g., phone calls, transformer explosions) with the position of the fire. From these data, points of maximal extent were spatially defined, and lines of common time were estimated by interpolating between known points, using general knowledge of factors affecting fire behavior. These "isochrons," or time lines of spread, reflect both spreading wave front advance and spot fire spread resulting from burning brand deposition. Particularly during the initial "blow-up" period, much of the fire's growth was attributable to spot ignitions, indicating significant unburned areas within a given time-step.

The positions of the fire's maximal extent at a given time and known locations of spot fires were then digitized into a geographic information system (GIS) over base layers reflecting the fire zone's topography and infrastructure (roads, parcel ownership, etc.). These spatial features were then used to help spatially define the fire's spread. This effort resulted in two maps of the fire: a map documenting the early spread period covering the first hour after escape (10-minute isochrons), and a complete spread map showing the entire spread period (1-hour isochrons).

Results and Discussion

The topography of the origin area can be described as very steep (30 to 70 percent slope), with a mixture of fuels of both wildland and domesticated vegetation types. Understory vegetation resulted in a well developed surface fuel layer, with added fuel continuity in both horizontal and vertical dimensions coming from an abundance of intermediate and mature Monterey pine (*Pinus radiata*). Significant areas of blue gum Eucalyptus (*Eucalyptus globulus*) were in the fire area, although not within the immediate (200 m) area of the fire origin. Interspersed throughout the fire area on all sides except the east were residential structures, contributing significantly to the total fuel load. We have estimated that the forested/residential areas where the fire started had in excess of 100 mg/ha of available vegetation fuels, with at least an equal mass of structural fuels in discrete, isolated areas (Sapsis and Martin 1994). Finally, the weather patterns on the morning of the fire showed classic extreme high hazard conditions associated with easterly "Diablo" winds. This meso-scale induced weather pattern resulted in high temperatures (>80^{o} F), very low relative humidity (<15 percent), and strong, gusty winds, with average sustained ridgetop winds of 20 mph, and gusts likely at 30 to 40 mph. Also, a relatively strong inversion layer at 600 m is thought to have contributed both to accelerated downslope winds and complex local wind patterns (Pagni 1993). Thus, all three sets of fire environment variables (fuels, weather, topography) could be characterized as being in extreme conditions.

After numerous hot spots became evident during the morning of October 20, active flaming fire escaped from the original burn perimeter at 10:58 a.m., with escape fronts occurring from both the lower south and middle west areas of the fire perimeter. The east flank fire expanded both south and east into a mixture of north coastal scrub and intermediate pine, causing the latter to partially crown and drive short-scale spotting to the southwest. The east flank expanded toward Grizzly Peak Boulevard fairly rapidly, indicating complex surface wind patterns, with significant eddying generating upslope (westerly) surface winds that drove surface fire spread, and overstory ambient winds determining direction

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of spotting materials. The west flank escape appears to have moved slower and to the west before getting into a ravine and working upslope toward Marlborough Drive at approximately 11:25 a.m. By this time, the fire had closed in around itself on the south flank and had spotted across Buckingham Drive into the area between Buckingham and Tunnel Road. Thus, at about 30 minutes after escape, the fire had moved significantly to the east, crossing over Grizzly Peak Boulevard; however, it was relatively contained on its westerly front, with isolated short-scale spotting and wind-driven frontal advance causing the ignition of a few houses along Buckingham.

During the ensuing 30 minutes (11:30 to 12:00) , the fire was to show an extreme "blow-up" phase, with long-range spotting coming initially from crowning trees, and later from structural fuels as houses became fully involved. During the 11:30 to 11:40 period, pines crowning on the east flank contributed to rapid spot development on the southwest area near Highway 24, while pine and eucalyptus crowning dictated the ridge spotting that eventually resulted in fire crossing Hwy 24 near the Lake Temescal parking lot, and the rapid ignition of the Hiller Highlands subdivision. We estimate that, by 12:00, in excess of 700 homes were burning, and the fire was spreading as three discrete fronts: flanking to the south toward Horse Ridge, backing to the north into upper Vicente Canyon, and moving directly with the overstory winds into the Rockridge area behind Lake Temescal.

During the next 2 hours, the fire continued to grow rapidly in size, both in wildland-dominated areas on the eastern and northern flanks, as well as in residential areas toward the west and south. Particularly in the dense residential areas, with relatively poor surface fuel continuity, individual homes ignited because of spot deposition, and then fire would spread to adjacent homes because of radiation and direct flame contact. In many instances, spot fires formed well downslope of an unburned area, then grew upslope during periods of favorable winds. The complexity of the wind pattern cannot be underestimated; strong evidence indicated surface winds varied in all directions, because of fire-induced winds, as more and more areas became involved and energy release rates increased (Pagni 1993).

By 2:00 p.m. most of the pure wildland areas had been consumed, and fire spread slowed considerably, owing to the discontinuous and coarse nature of the residential fuel complexes, and somewhat flatter terrain. By 5:00 p.m. the northern perimeter of the fire was determined, but spread continued in residential areas on the southern flanks, despite reduced winds. The Upper Broadway Terrace area showed a remarkably discontinuous spread pattern, with fire advancing by clusters of homes, then returning some hours later. By about 10 p.m., the final perimeter was determined, covering about 520 ha.

Conclusions

The Tunnel Fire showed extreme fire behavior due to complex interactions amongst fuels, topography, and weather, with early expansion or "blow-up" driven by a diffuse set of mass fires resulting from abundant deposition of burning brands into unburned areas. Later spread in more dense residential areas was slower and more discontinuous because of differences in fuel structure, suppression efforts, reduced weather severity, and more moderate topography. Further research is required to investigate specific relationships between fuel, terrain, and weather on extreme fire behavior. Specifically, the intermix of wildland and structural fuels across complex landscapes subjected to periods of extreme fire weather presents a challenge for fuel/fire behavior modeling. In particular, investigations of crown fires, and associated spotting and rapid fire expansion, should not be restricted to purely wildland settings (Anderson 1968, Rothermel 1991).

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Comparison of Fuel Load, Structural Characteristics and Infrastructure Before and After the Oakland Hills "Tunnel Fire"[1]

Scott L. Stephens Domingo M. Molina Ron Carter Robert E. Martin[2]

Abstract: Structures rebuilt after the Oakland Hills "Tunnel Fire" in 1991 are different in many aspects when compared to their predecessors. Data obtained from the city of Oakland indicate homes have been rebuilt 28 percent larger (square feet). About 50 percent of the homes destroyed have been rebuilt, and building permits have been issued for an additional 16 percent. New construction mandates facilitated by local and State laws have resulted in the following requirements: class A roofs, chimney spark arrestors, 1-hour siding for exterior walls, 30-foot clearance of wildland vegetation. Domestic vegetation is not regulated. Average structural fuel load consumed in the fire was 11.5 kg/m^2. Larger homes built after the fire will produce higher structural fuel loads. Improvements in infrastructure such as roads and water supplies have not occurred. Improvements have occurred in communication systems. Increases in structural fuel load accompanied by modest improvements in infrastructure may increase the fire risk in this urban/wildland intermix.

Vegetation is a critical fuel component in urban/wildland intermix fires. Without an active fuel management program, vegetative fuels will accumulate. Many vegetative fuels also have a large amount of fine fuels with a high degree of horizontal and vertical continuity; fuels of this type can produce extreme fire behavior when conditions are dry.

The structural fuel component of the urban/wildland intermix is often neglected. In many cases the structural fuel load can be larger than the adjoining wildland fuel load. Combustion characteristics are much different in structural and wildland fuels but both can affect fire behavior of intermix fires.

Changes in infrastructure, building materials and vegetation management have been slow or non-existent following most urban/wildland intermix fires. The public as well as local and State agencies have short memories after such events. Several positive steps have been taken after the Oakland Hills "Tunnel Fire" in northern California that will reduce the probability of such an event occurring again, but many other problems remain.

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This paper will review the changes which have occurred and will summarize the structural and wildland fuel consumed in the Tunnel Fire.

Methods

Wildland vegetation inventory was accomplished by using NASA false infrared aerial slides (1:6,000 and 1:12,000) taken after the Tunnel Fire. The slides were projected over a 1.0 by 1.3 meter map of the fire area and perimeters were drawn around each vegetation type. Numerous trips were then taken to the burned area to improve the map. This information was used to create a second map that was further improved by the use of a set of 32 aerial color prints (1:6,000) taken after the fire by Pacific Aerial Surveys. The final map was digitized, and areas of each polygon were calculated, by using the geographical information system ATLAS.

Structural fuel load was calculated by using the average amount of lumber used to build a home in the western United States (American Forest and Paper Association 1990). The land area occupied by structures was determined using the geographical information system. Structural fuel load was assumed to be homogeneous over the area occupied by the structures.

Information was obtained on post-fire construction from the City of Oakland. Local fire officials were contacted to determine concerns in this post-fire urban/wildland intermix.

Results

The fire perimeter enclosed 615.2 hectares and was divided into categories:

Vegetation Category	*Area (ha)*
Eucalyptus (*Eucalyptus globulus*)	132.1
Monterey pine (*Pinus radiata*)	56.3
Northern California coastal scrub	109.7
Grassland	2.9
Coastal scrub and grassland mosaic	28.5
Monterey pine and coastal scrub mosaic	2.3
Coast live oak (*Quercus agrifolia*) and coastal scrub mosaic	19.2
Structures	246.2
Highways	18.0

The number of structures totally destroyed by the fire was 2,305 (Gordon 1994). Assuming the average home uses 13,000 board feet of lumber to construct (American Forest and Paper Association 1990), this results in a structural fuel load of 11.5 kg/m^2 (50.8 tons/acre). This value of structural fuel load is conservative because it does not include any of the interior components of a structure, although it is in accord with the average United States structural fuel load of 14 to 21 kg/m^2 (Bush and others 1991).

Examination of post-fire construction permits indicates homes have been rebuilt on average 28 percent larger. Local requirements of new construction include class A roofs, chimney spark arrestors and 1-hour siding for all exterior walls. State and local requirements of a 30-foot clearance between structures and wildland vegetation are also enforced.

Domestic vegetation is not regulated by local or state agencies. Some domestic vegetation is highly flammable. The heat released from one mature tam juniper (*Juniperus sabina* var. *tamariscifolia*) surpassed 2 megawatts within 1 minute of ignition (Stephens and others 1993). In that study mature junipers were harvested and burned at different moisture contents. Results from that study (Stephens and others 1993) along with videotape of the Oakland Hills fire demonstrate that domestic vegetation can provide an efficient vector for transmitting fire into a structure.

Conclusion

Structures in the post-fire urban/wildland intermix in the Oakland Hills will be built with more flame-resistant materials, but increases in the size of the structures will increase structural fuel load. Infrastructure such as water supply and road systems has not been improved, increasing the fire risk in this urban/wildland intermix.

Wildland and structural fuels must be managed to reduce risk in the urban/wildland intermix. Domestic vegetation must also be managed to reduce risk in the intermix. Emergency infrastructure must be improved to reduce the loss of life and property from these fires. Firefighting helicopters could be used for initial attack on urban/wildland intermix fires. Early detection and response would be required for effective fire suppression using helicopters.

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FireNet —A Forum for International Curriculum Development in Fire Science and Management?[1]

A. Chris F. Trevitt[2] David G. Green[3] David B. Sapsis[4]

Internet, a world-wide information technology network, provides the opportunity to set up the exchange and retrieval of problem-oriented information. FireNet, an international information retrieval and exchange network for those interested in landscape fires, is one such forum, among many hundreds now in operation (Green and others 1993). Anyone with access to a networked computer system, or with a desktop computer and modem, can subscribe to FireNet. The network allows free correspondence among all subscribers on the list—land managers, researchers, educators—wherever they are located. In April 1994, FireNet maintained 200 subscribers from a number of countries around the world. In December 1994, there were 370 subscribers.

In addition to real-time communication possibilities, FireNet is also potentially a valuable educational tool, particularly as more organizations outside the university sector gain access to Internet. This expanded access implies that individual faculty or professional trainers take on the role of "education moderator," filtering material so that it is customized to their particular need or context (Green and others 1993). Thus, FireNet not only complements the role of the textbook by providing a window on current issues under debate—thereby affording access to more up-to-date supplementary material and ideas—but also encourages feedback to help ascertain the value of this information in the workplace. Further, it provides an enticing medium for fostering the cooperative development of computer-based curriculum materials in fire science and management.

Background

The development of computer assisted learning applications has been ongoing for the last few years, many taking advantage of new technologies for dispersal and presentation of information. For example, in Canada, Thorburn (1990) and Hirsch and others (1993) have pioneered fire-related developments using videodisk and hypermedia technologies for education and training purposes. In the United States, a new training development group (Cooperative Program for Operational Meteorology, Education, and Training), affiliated with the National Weather Service, has been charged with the responsibility for developing new computer-based distance education modules for in-service training, and they hope to begin work on a new fire-weather module in 1994 (Lamos 1993, personal communication). At the Australian National University, we have recently acquired experience in the design, development and implementation of a computer-based graphical analysis package for use by students in analyzing fire weather histories (Trevitt and others 1993), and fire management planning within a problem-based learning context (Trevitt and Sachse-Åkerlind 1994).

At the same time as these separate developments have been underway, increasing financial constraints have been experienced at public educational institutions and other principal national research and management organizations. Training sections in operational groups concerned with fire science and management are often highly understaffed, and updated course material development is frequently lacking. In the future, we need to exploit opportunities to work together more closely, pooling development efforts where appropriate, and saving on overheads incurred during on-going curriculum development. FireNet provides a unique opportunity to realize these gains by facilitating the transfer of digital materials over the Internet and thereby achieving savings for everyone.

Implications of Developing a Digital "Fire" Curriculum

As computer hardware becomes more and more economical, it makes inroads into more and more organizations. Simultaneously, the software that is now becoming available allows more and more sophisticated and cost-effective data and information storage, transfer and manipulation. FireNet provides a practical demonstration of some of the emerging ways to facilitate text and image retrieval and interchange between organizations and individuals. Hypermedia links via Internet are now also becoming feasible using the Hyper Text Markup Language (HTML) protocol implemented, for example, by the public domain browser application "mosaic," and this facility is

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also provided on FireNet (Green and others, 1993). This means that digital curriculum resources (e.g. text, images, video, sound) resident in the public domain on a computer node connected to the Internet in, for example, Victoria, Canada, can be accessed by managers, researchers, academics, or others with access to a similar networked computer environment in Canberra, Australia, and vice-versa.

What form could these "digital curriculum resources" take? Currently, some examples on FireNet are essentially text-only student reading materials used in the undergraduate unit "Fire Science and Management" at the Australian National University. Text is the simplest form to deal with. However, line diagrams and photos are urgently needed to supplement this text. A range of text, black-and-white images, and line-drawings are already available at Australian National University on a local Macintosh network, and these have been used for study purposes by undergraduate students since 1993. Copies of personal lecture notes as well as supplementary material have also become available (Trevitt and Sachse-Åkerlind 1994). Eventually, a library of relevant color slides, video, and sound segments is envisaged as well. Animated graphics, in a true multimedia environment, hold considerable promise for communicating particularly challenging abstract concepts such as those associated with diurnal variations in fuel moisture and fuel moisture changes at different depths below the fuel and soil surface. Developments of this sort have no real book-based analogs, and, like the work by Hirsh and others (1993), represent some of the new ways in which information technology can expand and extend the educational process.

In a subject-area such as "Fire Science and Management," an extraordinarily wide range of relevant material can serve as an information base for training and education. This breadth of material alone is good reason for institutions to share the burden of collation, synthesis, preparation of overheads for lectures, images, development of problem-based tutorials, etc. Most of us with similar professional interests and shared educational goals work in geographic isolation from one another and can benefit enormously from exposure to the ideas and experiences of others working with common educational objectives.

For those of us who are in academics, it also makes considerable sense to work closer to our operational counterparts, and learn about, and from, some of the frustrations and joys experienced in ongoing programs of professional training. Relevant contacts can be found across the board in forest and land management agencies, as well as in groups such as National Parks and National Weather services. Shared responsibility in developing relatively small (e.g., two to five pages of text plus a few diagrams) modules, dealing with one specific science topic or management aspect, or a case study of a past fire means that, together, we would quickly build up a repertoire of relevant resources that each of us could access. Provided these materials conform to certain recognized and established international standards, there should be minimal difficulty in ensuring that they are transferable by digital, computer-based means.

Conclusions

FireNet provides an opportunity for much cross-disciplinary, cross-institutional and international collaboration. The curriculum development effort required to comprehensively address all of the relevant science and management issues for training and education in "fire" exceeds the capacity of a single individual operating in isolation. By using digital media as a default standard, and the communication and information-exchange afforded by new computer networks, new opportunities are created for cooperative curriculum development.

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Lightning Strikes and Natural Fire Regimes in San Diego County, California[1]

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Abstract: Data from the Automated Lightning Detection System were analyzed for the years 1985-1990 for San Diego County, California. The density of lightning strikes was found to be positively correlated with elevation. Temporal analysis revealed that lightning occurs most frequently in the months of July, August, and September preceding the peak of Santa Ana wind activity in October, November, and December. This suggests that a natural fire regime for this region would be typified by frequent, low-intensity fires and that large, high-intensity fires would be relatively rare.

Lightning is the only significant natural source of wildfire ignition in southern California (Keeley 1981, Krausmann 1981, CDF 1986-1991, USFS 1985-1990). Therefore, in order to understand the characteristics of wildfire occurrence in the absence of human influences (i.e., natural fire regimes), it is necessary to determine the distribution and frequency of lightning strikes. Researchers have used meteorological records and reports of lightning-caused fires to estimate the distribution of lightning and its importance to regional fire regimes. However, weather reports tend to underestimate lightning activity (Wells and McKinsey 1993), and artificial structures interfere with the establishment of lightning ignitions (Minnich 1987). Reliance on these methods leads to underestimation of lightning activity and lightning-caused ignitions.

The advent of the Automated Lightning Detection System (ALDS) in 1985 by the Bureau of Land Management has given researchers a new source of information to evaluate the distribution of lightning strikes. ALDS uses a network of radar lightning detectors to triangulate the location of lightning strikes (German 1990). Studies utilizing ALDS data have been made for northern Baja California, Mexico (Minnich and others 1993) and Yosemite National Park (Van Wangtendonk 1991).

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Analysis

An Arc/Info geographic information system (GIS) was used to analyze the temporal and spatial distribution of ALDS recorded strikes. Density of lightning strikes was found to be positively correlated with elevation (Pearson's r = +0.902). The mean annual densities of strikes were calculated for 305-meter (1,000-foot) increments in elevation:

Elevation (Meters)	Strikes per Square Kilometer
0 - 305	0.228
305 - 610	0.297
610 - 915	0.313
915 - 1220	0.860
1220 - 1525	1.063
1525 - 1830	1.367
1830 - 2135	2.767

The temporal analysis revealed that lightning activity is concentrated in the late summer. August alone accounts for approximately 42 percent of the mean annual total of strikes. The strikes recorded for the months of July, August, and September account for 85 percent of the mean annual total. No other month accounts for more than 5 percent of the mean annual total. This high activity period precedes the season of most extreme fire weather, which is frequently coincident with hot, dry Santa Ana winds.

Studies of the occurrence of Santa Ana winds in southern California from 1951 to 1960 (Schroeder 1964) and in San Diego County from 1970 to 1979 (Latham 1981) reveal the following frequencies of Santa Ana winds:

Month	Schroeder and others (1964) 1951-60	Latham (1981) 1970-79
July	2	0
August	0	0
September	11	4
October	19	13
November	26	15
December	18	13

The three peak months of Santa Ana wind occurrence are October, November, and December. July and August, which are the peak months for lightning activity, have the lowest frequency of Santa Ana winds.

Conclusions

The following conclusions summarize the findings of this study:

- The density of lightning strikes is positively correlated with elevation.
- The period of maximum lightning activity is during the late summer months of July, August, and September.
- Lightning is much less frequent during the months of October, November, and December when the frequency of Santa Ana winds peaks.

From these conclusions, we can infer the characteristics of hypothesized natural fire regimes in San Diego County and how those characteristics have been altered by human influences. Fire records from San Diego County demonstrate that current fire regimes are dominated by human-caused ignitions (Krausmann 1981, CDF 1985-1990, USFS 1985-1990). Data collected by Krausmann (1981) and Keeley (1981) reveal that frequency of ignition in the current human-dominated fire regime peaks at between 300 and 900 meters elevation (1,000 and 3,000 feet). This alteration is due to human influences such as destruction of wildland habitats at low elevations, increases in human-caused ignitions near the urban interface, and the placement of electrically grounded artificial structures at high elevations (Minnich 1987).

Additional inferences can be drawn relating natural fire regimes to climatic variables. Lightning activity peaks during the months of July, August, and September when wildland fuels are usually dry enough to burn. Santa Ana winds occur infrequently during these months. This suggests that a lightning-dominated natural fire regime would be characterized by frequent, summer season fires of relatively low intensity. Less frequent, late season lightning storms could be followed by Santa Ana winds resulting in larger and more intense fires. In the recent past, the coincidence of human-caused ignitions and Santa Ana events has resulted in large, highly destructive fires. In a natural, lightning-dominated fire regime such episodes would be rare.

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Modern Fire Test Methodologies for Building Materials[1]

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Abstract: New fire test methodologies for building materials and related theoretical models are leading to improved fire hazard methodologies for a variety of situations, including structures in the wildland/urban interface.

Traditional fire test methods have represented the first step toward replacing material-specific code requirements with performance-based requirements for building materials. These traditional methods have provided data for only one specific exposure (White and Nordheim 1992). By testing materials at various external heat fluxes (Tran and White 1992), the data obtained are more useful in fire models and hazard assessments. The parallel developments of theoretical fire models and state-of-the-art test methodologies have made it possible to improve fire hazard assessments (DiNenno and Beyler 1992). The development of performance-based fire safety requirements that specify design objectives was a major topic at a recent conference (Worcester Polytechnic Institute 1991).

Fire Test Methodologies

Three modern fire test methodologies are: the lateral ignition and flame spread test (LIFT), the American Society for Testing and Materials (ASTM 1993a); the cone calorimeter (ASTM 1992); and the intermediate scale calorimeter (ICAL) (Shaw and Urbas 1993). At the USDA Forest Service's Forest Products Laboratory (FPL) in Madison, WI, we are using a LIFT apparatus to develop ignition criteria for the Structure Ignition Assessment Model (SIAM) (Cohen 1995, Tran and others 1992). SIAM is being developed jointly by the FPL and two USDA Forest Service Research Stations: Southern and Pacific Southwest. Test results from the LIFT include minimum external heat flux for and surface temperature at piloted ignition, and minimum surface temperature and flame heating parameter for lateral flame spread. Oxygen consumption technique provides a convenient way to obtain heat release data. The best known apparatus using this technology is the cone calorimeter. At FPL, we have modified our Ohio State University (OSU) apparatus (ASTM 1993b) to obtain heat release rates using oxygen consumption (Tran 1990). Reduced heat release rate is an important characteristic of fire-retardant-treated wood (LeVan and Tran 1990, Sweet and others 1993). We have used heat release data to predict test results (Tran 1992) for ASTM E 84 (ASTM 1991). Because of its small specimen size, the cone calorimeter can provide data only for materials. With its 1-m^2 specimen, the ICAL provides the ability to test assemblies (Urbas and Shaw 1993) and specimens that include joints and other nonhomogeneous characteristics of building materials in the field. The ICAL is being developed at the Weyerhaeuser Fire Technology Laboratory in cooperation with the American Forest and Paper Association. The method is currently being considered by ASTM Committee E-5 on Fire Standards.

Concluding Remarks

Modern fire test methodologies provide data suitable for theoretical models and a range of fire exposures. As a result, we are better able to develop fire hazard assessments for a variety of situations, including structures in the wildland-urban interface. Better fire hazard assessment methodologies and specific design objectives will lead to code requirements that provide a high level of fire safety and design flexibility.

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Brush Fire Hazard: An Analysis of the Topanga Fire Storm[1]

James A. Woods[2]

In the fall, the annual Santa Ana winds blow from the high deserts of the Western United States, over the San Gabriel Mountains and through the greater Los Angeles Basin. When fire is introduced into the chaparral ecosystem of southern California, these hot, dry, nearly hurricane force winds can generate immense fire storms. This is precisely what happened for a 2-week period starting in late October and ending in early November 1993. More than 20 major brush fires burned during this time. One devastating fire, in particular, was the Topanga Fire Storm. This fire was started by an arsonist around 10:40 a.m. on November 2, and over the course of the next 5 days, burned over 16,500 acres, destroying or damaging nearly 350 homes.

Fire is an integral part of the chaparral environment of California, and as urban areas expand and encroach into wilderness regions, the need to establish the level of fire hazard in a region increases. Geographic information system (GIS) technology is a valuable tool in fire management (Gronlund and others 1994, Salazar 1989). One application of GIS technology to the wildland/urban interface problem has been the replication of fire hazard models (Woods 1992).

GIS Technology

Woods (1992) used two different GIS's—IDRISI, a raster-based GIS, and Atlas GIS, a vector-based system—to replicate several fire hazard models. He showed that the distribution of fire hazard can be vastly different for a given area, depending on which methodology is used. The three models used were: the Burning Index model, used by the California Department of Forestry and Fire Protection (Phillips 1983); Schmidt's Fireline Intensity model (Schmidt 1978); and the Los Angeles County Fire Department's Brush Fire History Hazard model (Pierpont 1991).

A portion of the Santa Monica Mountains, in Los Angeles County, was used as the study area. The geographic variables which each model used (topography, vegetation, brush fire history, etc.) were digitized and stored as separate images and layers in both IDRISI and Atlas GIS, respectively. These images and layers were then analyzed, combined, and compared on the basis of each hazard model's guidelines, to replicate the hazard models. The final models were then stored as images and layers.

Because the Topanga Fire Storm was located wholly within the confines of the study area used by Woods (1992), all of the data necessary for an analysis was pre-existing in his data base. The only operation necessary was for the perimeter of the Topanga Fire Storm to be digitized and stored in both GIS's. That portion of each fire hazard model which fell within the confines of the Topanga fire could then be extracted to create new images and layers. These new images and layers represent what the level of fire hazard was, per each original fire hazard model, within the fire zone.

Comparison of Fire Hazard Models

The three models use different criteria for determining the level of hazard, but each of them divides fire hazard into three categories, making a comparison relatively easy. Though each model uses different terms to describe their level of hazard, for this paper, the terminology will be: Low, Medium, and High.

Analysis of each of the models indicates that the Fireline Intensity model and the Brush Fire History model are much closer to each other in the percent of land in each hazard category, while the Burning Index model was quite dissimilar to each of the other two. The Fireline Intensity model places 38.2 percent of the land in the Low hazard category, 25.1 percent in the Medium, and 36.7 percent in the High, while the Fire History model places 21.9 percent of the land in the Low hazard level, 37.4 percent in the Medium, and 40.7 percent in the High. The Burning Index model, on the other hand, places only 2.7 percent of the land in the Low hazard level, 50.2 percent in the Medium, and 47.1 percent in the High fire hazard level.

However, a visual analysis of each of the maps indicates that there is great disparity between all three models. The Fireline Intensity model (*fig. 1*) and the Burning Index model (*fig. 2*) have a similar underlying pattern, since vegetation is one of the most important factors in each model. The Burning Index model also incorporates slope, which accounts for the discontinuity of hazardous areas. Since the Fire History model (*fig. 3*) is based solely on the fire history of the region, there is no influence from either vegetation or topography. The Low category, in the original model, represents 1-10 years since the last brush fire. Medium represents 11 to 29 years, and High represents areas which have not burned in

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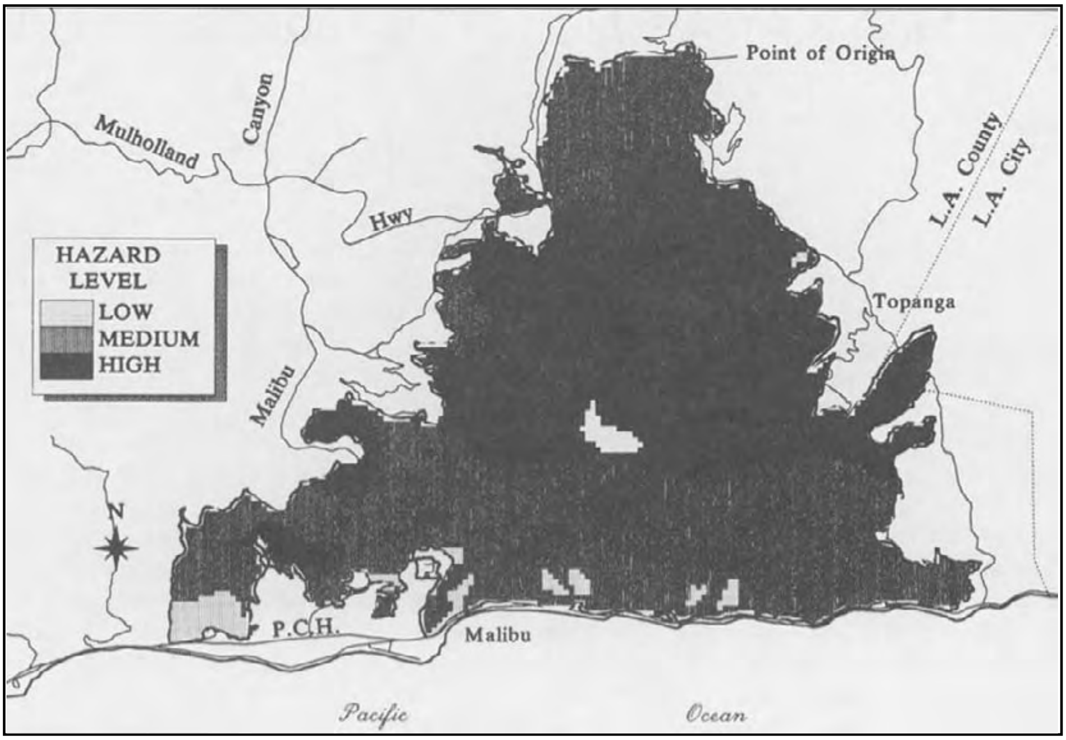

Figure 1– Fireline Intensity fire hazard model of the 1993 Topanga Fire Storm.

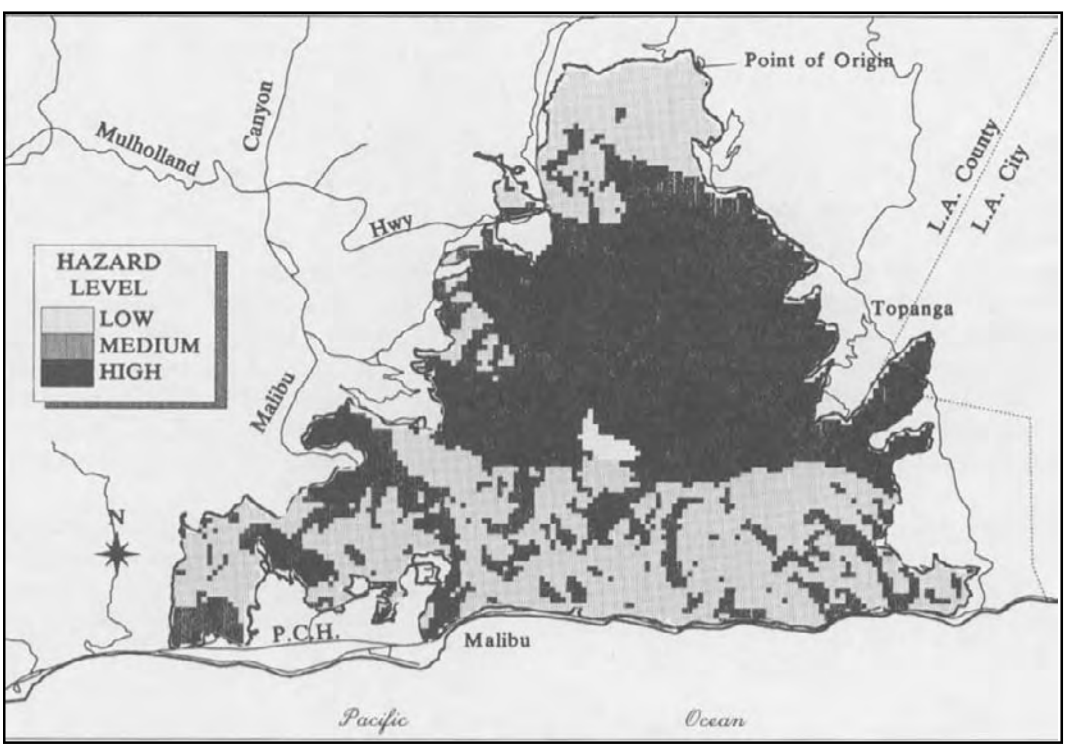

Figure 2– Burning Index fire hazard model of the 1993 Topanga Fire Storm.

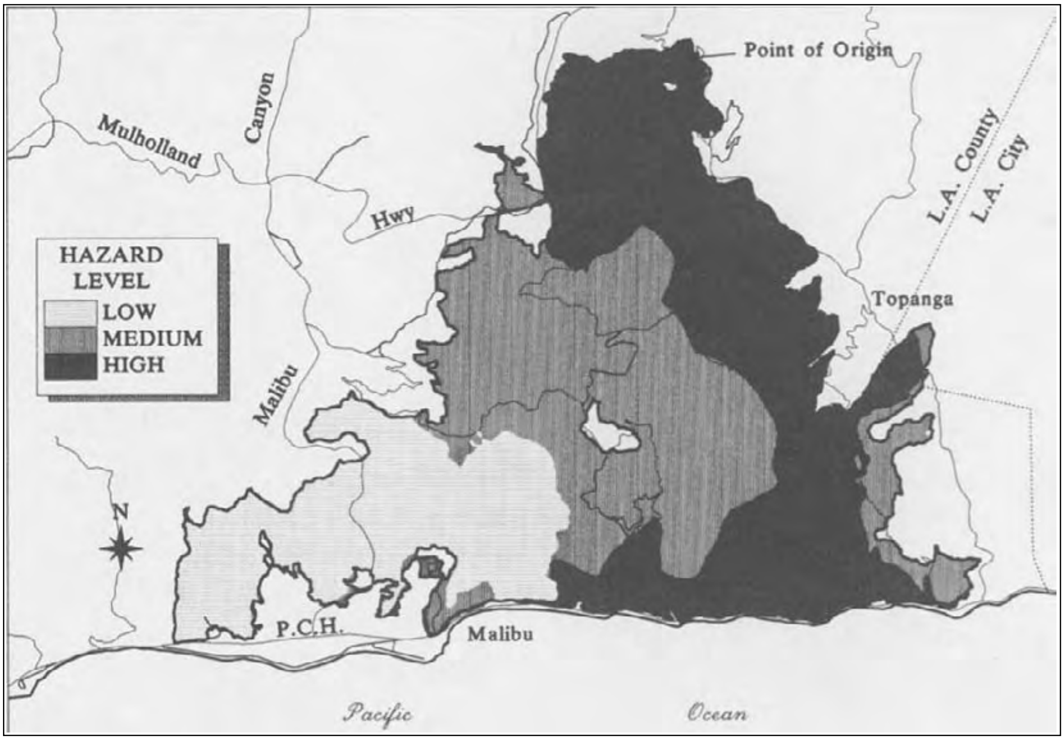

Figure 3– Brush Fire History fire hazard model of the 1993 Topanga Fire Storm.

more than 30 years. As a result, the fire history map becomes a vegetation age map.

None of these models are designed for use as a predictive tool. The Burning Index model is designed to define where the potential fire hazard is so that building codes can be implemented, whereas both the Fireline Intensity and Fire History models are designed to help with fire response planning. Further research would be to implement a fire simulation model, such as FIREMAP (Ball and Gurtin 1991), and then make a comparison between the actual fire and the computer-simulated fire.

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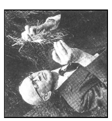

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