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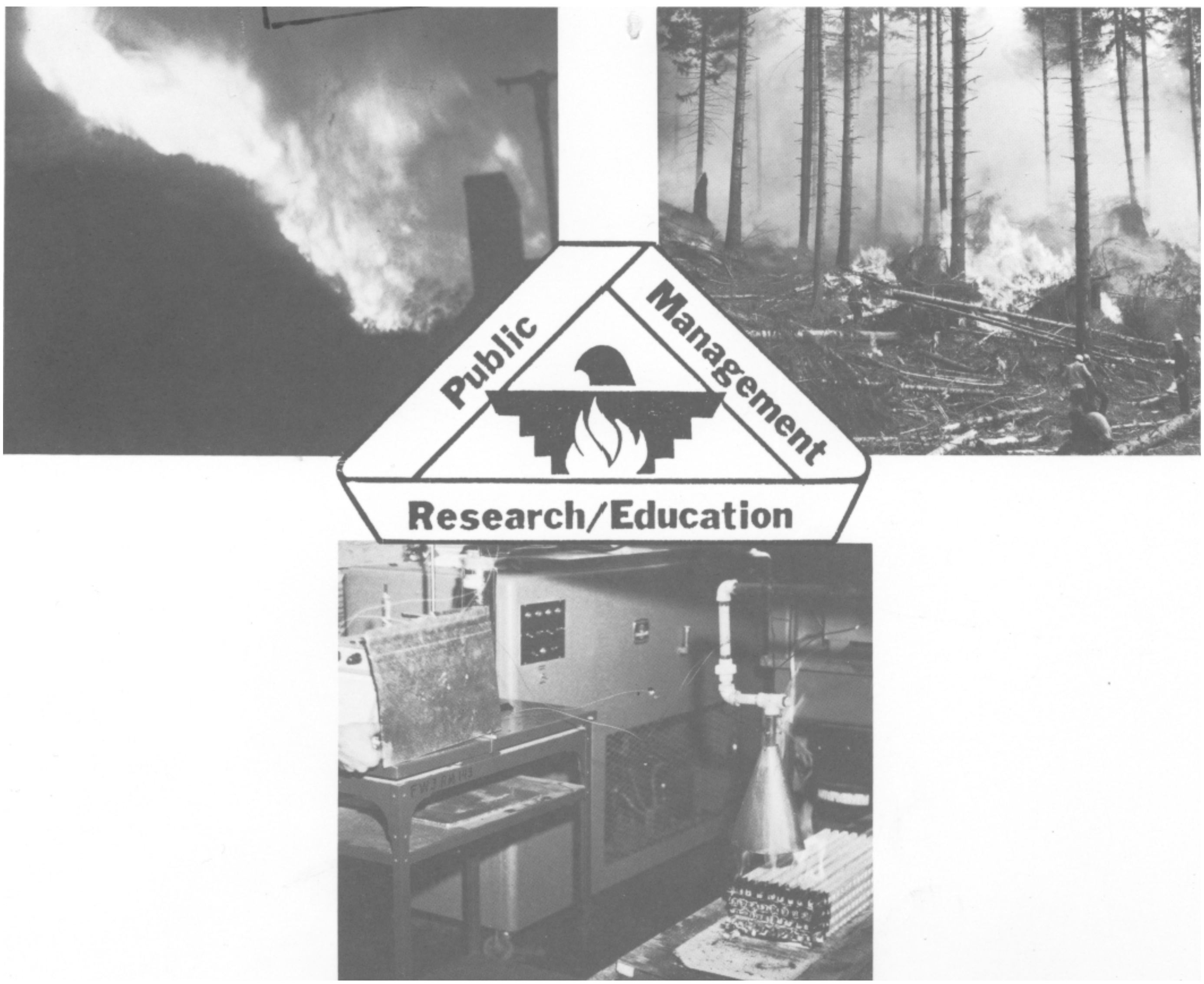
Proceedings of the Symposium on

Wildland Fire 2000

April 27-30, 1987, South Lake Tahoe, California



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Technical Coordinators

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PREFACE

Two years in the planning, the symposium on Wildland Fire 2000 was held April 27-30, 1987, at Stanford Sierra Camp on Fallen Leaf Lake, near Lake Tahoe, California. We first proposed the symposium in spring 1985 to Charles W. Philpot, who was then Director of Forest Fire and Atmospheric Sciences Research of the Forest Service, at the Conference on Fire Management--Challenge of Protection and Use, in Utah. He became the first supporter of the symposium. In addition to the Forest Service, sponsors were the Bureau of Land Management and the National Park Service, U.S. Department of the Interior; California Department of Forestry and Fire Protection; International Union of Forestry Research Organizations; the Society of American Foresters; and the University of California.

Many individual fire agencies have held futuring sessions to discuss their particular problems and visions, so why a symposium? Wildland Fire 2000 brought together practitioners, scientists, educators, and the public from several countries to consider the possible, probable, and preferred status of wildland fire management and science in the year 2000 and beyond. The organizing committee thought the symposium could pull together a broader range of persons with expertise or concerns about the future of wildland fire. On the basis of the attendance, it succeeded.

The organizing committee was formed using the Incident Command System (ICS) with duties assigned as suggested in an organization chart developed by Delmer L. Albright of the California Department of Forestry and Fire Protection (see his paper, these proceedings). This organization worked well, implicitly assigning duties to each member of the organizing committee and providing a structure for handling problems that arose during the symposium. Use of the ICS also provided the chance to familiarize those outside the fire service with its structure and function.

The logo for the conference was developed to represent three basic aspects of wildland fire management: public needs, resource management, and education/research. Because the combustion and fire behavior triangles are well known, we used a triangle as the basis of the logo, with the three sides representing the three different aspects of fire management.

Lest it appear that this arrangement put the three groups at odds with each other, we made the triangle from a Moebius band. Thus, the three groups are on the same face of the band, as one would find by actually tracing around it. Indeed, all three groups are on the same side of the problem, trying to reduce the negative impacts of wildfire and to increase the positive effects of fire use. Understandably, all do not always see the problem in the same light, but then, one of the purposes of Wildland Fire 2000 was to see each other's viewpoint more clearly.

The technical sessions began with the needs of the public--the logical starting point of the conference. The next session dealt with the response of management to these needs, as well as the needs of management. The third session addressed the response of the education and research communities and their needs. The next session was devoted to nine individual futuring groups, each of which outlined its perception of trends, visions, and strategies for a specific subject area. The individual futuring sessions were considered by many to be a highlight of the symposium. The futuring session was followed by one on interactive or international concerns, and the final session was a report by the individual futuring groups.

The needs of the public were discussed from a sociological viewpoint, both in terms of long-term trends and short-term demographic changes. The projected nature of wildlands as well as the impacts of fire on them and public perception of these effects are important concerns of managers. Smoke management is becoming more constraining. Eventually, planning will include fire considerations at the local level, as government and the public become more aware of the problems of dealing with vegetation/structural fires.

Great improvement in the efficiency and effectiveness of fire management is foreseen over the next several years. Much of the improvement in efficiency will be dictated by more stringent budgets and budgeting processes. Better planning, involvement of local agencies, and sharing of resources among all protection agencies will be major factors in improving efficiency and effectiveness. Technical improvement in techniques and equipment will contribute to the improvement in management.

The education and research community sees several areas for improvement in the products available to management and the public. Weather forecasting, fire behavior prediction, and fire effects information should all lead to improved fire management. The field of artificial intelligence and its subfields of natural language, robotics, and expert systems, along with rapid improvements in computers, will result in better accumulation, assimilation, and use of acquired knowledge.

Internationally, many problems are foreseen in the developing nations. Their populations and demands for goods and services are increasing, as are the damages from wildfire. Loss of tropical and subtropical forests is occurring, often with use of fire, and generally policies are inadequate to cope with wildland fire. A bright spot is the improving program in international assistance for natural disasters.

The results of Wildland Fire 2000, we anticipate, will be a revitalization of efforts to improve fire management. In the logo, the phoenix is depicted as rising from the flames, not so much to indicate that we have been burned in the past, but more to symbolize revitalization of our efforts to suppress and use fire more wisely in cooperative efforts. These cooperative efforts among the public, management, and education/research should lead to better protection and management of wildland resources and the related wildland-urban interface.

Wildland Fire 2000 provided an interagency, interdisciplinary, and international look at wildland fire in the future. It was not the first and will not be the last futuring meeting to deal with wildland fire. A sequel to this symposium is scheduled at Fallen Leaf Lake for spring 2001.

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Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Adapting the Incident Command System to Meeting or Conference Management[1]

Delmer L. Albright[2]

The incident Command System (ICS) is perfectly adapted to managing a large meeting or conference. The primary purposes for using ICS are these: (1) The staff needed for a conference is already developed and duties are well outlined; (2) the incident management process (including forms) is readily adaptable to a conference; and (3) the ICS system is gaining wide acceptance and makes a large meeting or conference much easier to conduct.

This paper provides procedures, samples and recommendations for the meeting/conference Incident Commander to design a conference and develop an ICS organization. The information and samples contained herein are taken from over a dozen conferences that used the ICS organization.

KEY INGREDIENTS

Based on conference critiques and participant evaluations, there appear to be 10-key ingredients to a successful ICS conference:

1. Staff
2. Game Plan
3. Planning Meetings
4. Visualization
5. Logistics
6. Active Participants
7. Time Schedule
8. Social Activities
9. Checks and Double checks
10. Professionalism

Each ingredient is discussed below.

Staff

Develop an ICS staff and "staff up" just like for an emergency incident. Fill positions as the incident expands. Plan ahead and assign staff in the early stages of conference planning if at all possible. As a minimum, at the start of any large meeting/conference planning session, the following staff is required:

Incident Commander
Operations Section Chief
Logistics Section Chief

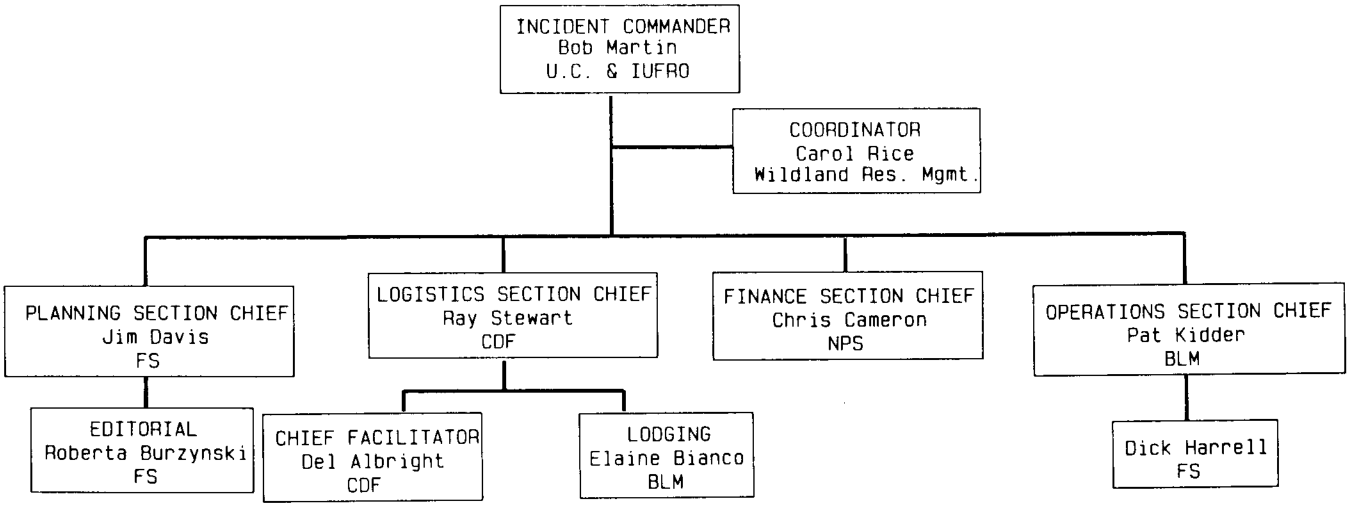
Operation staff may include any of the ICS positions, but the most common are these:

Finance Section Chief
Information/Press Office
Planning Section Chief
Facilities Unit Leader

One major mistake is waiting too long before including key staff in the planning process. For example, registration procedures should be developed with the Registration staff.

[1]Prepared for the Proceedings of the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

[2]Deputy Logistics Chief, Symposium on Wildland Fire 2000; and Presuppression Division Chief, California Department of Forestry and Fire Protection, San Andreas. California.



ICS staff organization for Wildland Fire 2000.

Game Plan

Write and publish a Game Plan. The Game Plan should be built around the agenda and provide a complete listing of duties to be performed by each staff person and at what time. Game Plan is a conference term of the tactics of the Incident Action Plan.

The Incident Action Plan, which includes the Game Plan, tells the staff what is expected of them and their roles in the incident. It clarifies lines of communication and chain of command as appropriate. It also serves as a reference document for future similar efforts.

Planning Meetings

Conduct a planning meeting as soon as possible in the early stages of conference development. At least gather the minimum ICS staff together and begin organizing the conference details. It is usually beneficial to include as many staff as possible in planning sessions due to the value of group brainstorming. As a general rule, a planning meeting should be held once every day during a conference.

Visualization

Visualization is a process that is very helpful in planning conferences. The common slogan that comes from the military is "Close your eyes and visualize." It means imagining the entire conference by mentally walking through each step; from developing the announcement, to parking, to walking up to the registration table, to leaving the conference. Visualization is most useful in the initial planning stages.

As each step is visualized, make a flip chart list of the various duties (tasks) that need to be performed. It is usually helpful to assign these duties to someone on the staff at the same time.

For example, while visualizing the registration process, ask yourself "what would I need/want to know about registration if I were attending the conference?" Then develop the flip charts. They might look like this:

****

Facilities Unit Leader

- determine hotel primary contact
- obtain hotel menu
- arrange for registration table and chairs
- find out about parking restrictions

Logistics Section Chief

- request logistics staff
- develop logistics handout for registration packet
- develop lunch menu

****

For each step of the conference, repeat this process. If practical, assign due dates to important tasks right on the flip chart lists. Have the flip charts typed and incorporated into the Game Plan. Send a copy to everyone on the staff. If desired, it is then easy to develop a time schedule for conference planning.

For large and complex conferences with large planning staffs, especially from different agencies, sometimes it is helpful to summarize staff assignments on one page.

Logistics

If anything can mess up a conference, logistics can. They must be as smooth as silk. Most importantly, the logistics section must be solely responsible for dealing with the conference facility. If too many people begin giving instructions to the facility representative, then confusion is inevitable. ONLY ONE PERSON SHOULD HAVE THE RESPONSIBILITY AND AUTHORITY TO COORDINATE DIRECTLY WITH THE FACILITY REPRESENTATIVE. This person should work for the Logistics Section Chief who would be informed of what is going on, and be the back up contact. A Facilities Unit Leader can be a good choice for a primary facility contact.

A Logistics Plan may be written. It can be incorporated into the Game Plan or be part of the Incident Action Plan. It should cover all logistical details important to the staff, including meals, rooms, travel, supplies, requisitioning, lodging, inclement weather, registration, mailing, and finances (if coordinated with the Finance Chief).

Active Participants

According to the experience of the authors. the most successful conferences are those that are participative to some extent. This means having the participants actually do something besides listen to presentations. The entire conference doesn't have to be participative; just some element of it to add a dimension beyond listening to papers. In a 3-day conference, 1 day of participative activities can be sufficient to make the conference a notable success.

Participation can be in several forms: small group breakout meeting; futuring exercises; concurrent panel sessions; small group discussions; "round-robin" lecturettes; and others where the participants are moving around and doing something besides listening. Alternating between conference papers and small group exercises is an effective way to keep the participants alert, interested, and involved.

Participation can lead to ownership in the outcome. Ownership can result in continued communication after the conference. Continued communication gives life to the conference and makes it more meaningful than just a couple days out of the office.

Time Schedule

Everything needs to stay on time. People judge conferences by the timeliness of events. Participants and speakers should be given an agenda (time schedule), and it should be followed. The most important times to adhere to are the starting and ending times of the conference because of travel arrangements.

Social Activities

Design social activities into the conference. Start in an afternoon so there can be a social activity the first night. This tends to initiate communication and draw the participants closer together as a group. For extended conferences at known recreational sites, design time into the agenda to enjoy free time. People will tend to do it whether or not you include it.

Checks and Double Checks

Murphy's Law is alive and well in conference planning. Every key staff person should spend a lot of time checking and double checking details. The Logistics Section is especially prone to problems. A-V equipment, room arrangements, and meal times seem to be very susceptible to mix-ups and let-downs.

Professionalism

A conference should be conducted like a business with professionalism in the staff as an uppermost concern. Poor logistics and even confusion can be overcome by a courteous and professional staff.

INCIDENT ACTION PLAN

The ICS forms associated with the Incident Action Plan (IAP) are quite appropriate for conducting a conference. The IAP is written early in the planning stages or on site just like during a major emergency incident. The Operations Section Chief can fill both roles.

Here are examples of using the ICS forms to develop an Incident Action Plan.[3]

Incident Briefing; ICS Form 201

Form 201 is used for conference location, dates, and chain of command.

Incident Objectives; ICS Form 202

Be as specific as possible when developing objectives, but such statements as "logistically smooth," and "professional image" are OK. If appropriate, specify objectives like "develop 10-key issues."

Organizational Assignment List; ICS Form 203

When the staff arrives at the conference, specify staff assignments within the ICS structure. People may occupy more than one job. For example, the Medical Unit Leader can also be the Safety Officer. The Service Branch Director may also fill the Communications Unit Leader Job. If attendees are broken into teams/small groups, assign Division Supervisors to coordinate them.

Division Assignment List; ICS Form 204

This form is especially useful for small group/team breakouts. Teamleaders, meeting locations and group topics can be specified. This is completed by the OPS Section Chief.

[3] Samples of the forms are available from the author.

Incident Radio Communication Plan; ICS Form 205

This is the ideal from for assigning radios and call signs where appropriate. It is completed by the Communications Unit Leader. Handi-talkie radios can be very useful in conference management.

Medical Plan; ICS Form 206

A Medical Plan is a good idea for any conference. It is completed by the Medical Unit Leader.

Check In; ICS Form 211

This form is used especially to check in staff. Specific items of equipment, such as flip charts easels and staff room locations, can be identified by making minor modifications to the form. Registration personnel complete this form.

Operational Planning Worksheet; ICS Form 215

This form can be used with some modifications. Columns can be relabeled to assign team leaders, facilitators, Division Supervisors. etc. It can also be used by the Supply Unit Leader to distribute and account for items like flip charts and easels.

Support Vehicle Inventory; ICS Form 218

To be filled out by the Ground Support Unit Leader. This form keeps track of staff vehicles in the event shuttles are necessary.

DEMOBILIZATION PLAN

Besides the Incident Action Plan, the Demobilization Plan is another useful ICS document. It is completed by the Demobilization Unit Leader. This form ensures everyone on the staff goes home with all their bills paid, keys and supplies turned in, and on time. A one-page check-out form can be developed that standardizes the check-out procedures for each staff member.

The demobilization plan should include five sections:

1. General--discussion of demobilization procedures.
2. Responsibilities--specific duties and activities.
3. Release Priority--according to agency, travel distance and other priorities.
4. Release Procedures--process to be followed.

STAFF RESPONSIBILITIES

ICS conference staff responsibilities usually are divided as follows:

Incident Commander

* overall guidance; direction
* "politicking"
* key-staff supervision
* strategy development/implementation
* maybe serving as Program Chair
* arranging for speakers
* acting as or appointing Safety Officer

Operations Section Chief

* staff coordination/supervision
* agenda (program)
* maybe serving as Program Chair
* writing Game Plan (tactics)
* maybe supervising Facilitators
* developing conference organization
* trouble shooting
* monitoring time schedule

Logistics Section Chief

* facility coordination
* menus and meals
* supplies
* A-V equipment
* lodging and rooms
* writing logistics plan
* registration/information
* messages
* travel
* spousal programs
* communications (radio, phone)
* services, support, maintenance
* medical plan
* ordering, receiving, distributing
* security
* vehicles/parking/signs

Finance Section Chief

* paying bills
* budgeting
* cost analysis
* contract administration
* staff time keeping
* compensation classes
* honorarium disbursements

Planning Section Chief

* Incident Action Plan
* resources status
* situation status
* conference documentation
* demobilization supervision
* specialist consultant supervision
* planning meetings
* IC support
* press/public relations
* press room
* information table
* news releases
* VIP's and dignitaries

Other positions should be filled, as appropriate, with duties corresponding to a similar position on an emergency incident using ICS. Consult the Incident Command System publication ICS 420-1, Field Operations Guide for further details.

SUMMARY

ICS is well suited to conference management. It provides for a smooth, well-organized conference, with most of the organizational work already developed.

Like any sophisticated management system, the use of ICS requires trained personnel in the key staff positions. But the effectiveness of ICS is worth the effort to establish it.

ACKNOWLEDGMENTS

The members of the organizing committee were largely responsible for the success of the symposium. Robert E. Martin, University of California, headed the committee. Carol Rice, Wildland Resource Management, served as coordinator, capably and cheerfully handling a wide range of duties.

Jim Davis, Pacific Southwest Forest and Range Experiment Station, served as Planning Section Chief with a major responsibility being preparation and compilation of the papers in these Proceedings. Roberta Burzynski, also of the Station, edited and coordinated the individual papers. Robert E. Martin helped compile the Proceedings.

Ray Stewart, California Department of Forestry and Fire Protection, was Chief of the Logistics Section. In addition to their participation in the planning process, the logistics crew handled all the on-site needs for the symposium. Del Albright, CDF, arranged for the facilitators and recorders for the futuring session. Elaine Bianco, Bureau of Land Management, handled lodging and with Betty Bechtel, California Department of Forestry and Fire Protection, registered participants. Under Ray's able guidance, Jim Mierkey, Rich Schell, Don Perkins, Wayne Mitchell, and Glen Lee--all of the California Department of Forestry and Fire Protection--kept everything running smoothly.

Chris Cameron, National Park Service, served as Finance Section Chief, overseeing all monetary transactions.

Pat Kidder, Bureau of Land Management, served as Operations Section Chief, assisted by Dick Harrell, Pacific Southwest Region, Forest Service.

A keynote address by Ralph Cisco, Supervisor, Tahoe Basin Interagency Management Unit, Forest Service, and a welcoming address by Gerald Partain, Director, California Department of Forestry and Fire Protection, started the meeting off with a flourish. The session chairs ably kept the conference moving along smoothly, handling all the sessions with aplomb. Session chairs were Don Grant, Michigan Department of Natural Resources; Management Response and Needs--Bill Teie, California Department of Forestry and Fire Protection; Research Response and Needs--Peter Roussopoulos, Forest Fire and Atmospheric Sciences Research Staff, Forest Service; Futuring Sessions by Topics in Small Groups--Jack Wilson, Bureau of Land Management; and for Interactive Papers with International Focus--Phil Cheney, Commonwealth Scientific and Industrial Research Organization, Canberra, Australia.

The small group futuring sessions, which were a highlight of the meeting, were successful largely due to the excellent efforts of the facilitators and recorders: Gary Brittner, Stan Craig, Don Escher, Frank Goddard, George Haines, Fred Imhoff, Tim McCammon, Tom Osipowich, Chris Parker, Wendell Reeves, Jesse Rios, Bob Robeson, Chris Schrowe, Bill Schultz, Bob Signor, Dan Ward, Ed Wristen--California Department of Forestry and Fire Protection; and Karen Barnette, Lorna Burleson, Howard Carlson, Ken Larsen, Nancy Mac, Christy Neil, Joanne Roubique, Randy Scurry, Karen Shimamoto, and Scott Vail--Forest Service. The following individuals compiled the futuring reports from notes recorded during the small group sessions: Wayne Harrison, Clinton Phillips, John Hatcher, Don Latham, Charles George, Joe Rawitzer, James Davis, Patricia Andrews, and Johann Goldammer.

Alex Dimitrakopoulos, Mark Finney, Paula Minton, and Dave Sapsis, graduate students from the University of California, timed the speakers and operated projectors during the presentations.

The friendly and capable staff of Stanford Sierra Camp helped make the symposium work by providing satisfying meals and accomodations [sic].

Finally, the most important component of the symposium was the participants, who shared their thoughts through their presentations, contributed to the discussions, and gave their ideas for the futuring reports.

We thank all these people for the success of the symposium.

Presented Papers

Community Needs
(*What are the problems?*)

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Community Fragmentation: Implications for Future Wildfire Management[1]

Robert G. Lee[2]

Abstract: Two meanings of human community compete for public attention: (1) community as a sense of belonging to a particular social group within a society, and (2) community as a global ideal consisting of political expression. religious fulfillment, and/or harmony with the world at large. The latter meaning has become increasingly prevalent as we approach the year 2000. This idealistic sense of community is represented in the Clementian theory of ecological succession that formed traditional fire suppression practices. Modern fire management, as practiced by the Forest Service, U.S. Department of Agriculture, is a very recent attempt to substitute rational fire management and particularistic thought for fire suppression practices motivated by such unrealistic ideals. There are signs that rational fire management, as legitimated by responsiveness to particular social groups, is competing with the pursuit of an ideal of a self-regulating natural world--where a "natural harmony" is produced by cycles of disturbance uninfluenced by human volition. Such "millennial fire management" substitutes idealism and aristocratic suffrage of fire scientists for particularistic social and political processes used to identify fire management objectives. Will the year 2000 bring the return of fire to the "Act of God"--even though it is a god whose design for natural ecosystems is revealed by scientists?

"Wildland Fire 2000" is a theme pregnant with meaning for a sociologist. The celebration of a 1000 year anniversary takes for granted the parochial origins of our calendar and invests the arrival of a given year with extraordinary significance. Despite our pretense of rationality, the year 2000 suggests to many the coming of transformation--even a millennium, "a period of great happiness or perfect government or freedom from imperfects in human existence." (Websters) The phoenix--the logo for this conference--symbolizes this expectation of transformation; like the setting and rising of the sun, life will rise again from the fires of destruction.

Reflections on this theme released a stream of images that tell a story fundamental to contemporary fire science and management. But contrary to most stories, after an extensive preface, this tale opens with the present strivings to anticipate a future beyond the wall of the year 2000, and then proceeds to reconstruct in reverse order the historical sequence of events that gave rise to the present. Reversal of this story is especially revealing because the meaning of present and future events is to be discovered in the continuity of past beliefs and practices. Moreover, those similarly disinclined to accept linear concepts of progress may, along with T.S. Eliot, discover that

> . . . the end of all our exploring
> Will be to arrive where we started
> And know the place for the first time.

My principal device for discovering the future of wildland fire management in the past is to review the sociological origins of applied ecological thought. Emphasis will be placed on review rather than research because the sociology of ecological knowledge has been examined by others far more skilled in historical scholarship (see especially Tobey 1981, Schiff 1966, and Schiff 1962). Remarks

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[1]Presented at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

[2]Professor and Chair, Division of Forest Resource Management. College of Forest Resources, University of Washington, Seattle.

will be limited to summarizing past work, interpreting modern fire management in light of accumulated work, and suggesting fruitful directions for future research.

PRELIMINARIES: IBSEN'S "LIFE'S-LIE"

There is little novelty to the idea that the structure of human communities influences how people think about the behavior of the natural world. But we find it easier to see where we have been than where we are now or where we are going. The sociological origins of Clementian ecology are clear to modern observers who take the time to examine the social and ideological origins of this pioneering school of ecological thought (Tobey 1981). We find it relatively easy to assert that Frederick Clements' theories were affected by his social circumstances. Yet is is generally unthinkable--and an affront to our pride in rationality--that our current ecological theories and practices may reflect our social circumstances. Somehow each generation of scientists believes that enduring truths are in sight, if not already in their grasp. How comfortable we are to have replaced the fanciful pursuit of fire control with the certainties of rational fire management!

But is our sense of pride and self-assurance only possible because we have been successful in imposing a convincing system of thought on a turbulent flow of events? Is it simply another form of self-deception to act as an agent for nature by purposely imposing "disturbance events" as surrogates for wildfires? I will discuss this possibility below, and mention it here to illustrate how we attempt to simplify the diversity and complexity of the world around us by abstracting selected elements of our experience. At one point in human history fire is an alien, destructive force, yet only a few years later it is the agent for regeneration and perpetuation of natural systems.

All systems of thought necessarily focus on some things and ignore others, and can only be maintained by denying the reality of experiences that contradict commonly accepted understanding of what is happening (Bailey 1983). Since simplification is necessary for all thinking, we cannot avoid disregarding some experiences in favor of others. This is contrary to our common sense, which tells us that our actions always conform to cultural patterns and rational explanations. Bailey (1983) cites Ibsen's Wild Duck as poignant illustration of the inevitability of inhabiting a make-believe world in which we pretend reality takes a form we secretly or unconsciously know it does not take. Ibsen referred to this common-sense pretense as "life's lie," and suggested its abrupt revelation yields only a nihilistic hell.

Few contemporary scientists would disagree that the history of wildfire control in North America involved denying our experiences of the beneficial functions of fire as a natural process. Schiff's (1962) masterful critique of wildfire research in the Forest Service, U.S. Department of Agriculture, interprets the fire researchers' own "life's lie"; following from Clements, fire was conceived as an alien, disruptive event that interrupted the progressive development of vegetation toward a stable climax.

Yet are we any less likely to deny our experience than was Frederick Clements and his followers in the Forest Service? Do we share a "life's lie"? And how do we reveal our denials of experience without falling into the hellish pit Ibsen forced us to confront in the final act of Wild Duck? Answers to these questions will help us transcend the present enough to understand how the future is contained in the past. We certainly can't see through the wall we have imposed by emphasizing the year 2000 without becoming more conscious of our make-believe worlds. And perhaps we will even discover that the "future" is, like all simplifications, a myth we invent to satisfy an urgent need to understand what is going on in the present.

My vantage point for viewing our future approach to wildfire is to review what is known about forms of human community in the present and past with the purpose of anticipating the future. The last section of this paper will be devoted to a discussion of the relationship between changes in human community and systems of ecological thought that guide wildfire policy. Particular attention will be given to the implications of contemporary fragmentation in the national sense of community. However, this discussion will be prefaced by a methodological note on how denials of reality embedded in conventional wisdom can be revealed constructively.

THE POLITICS OF REVELATION

When as an undergraduate forestry student I first began to study the history of wildfire control in the United States, I presumed that the leaders of the Forest Service and other land management agencies naively believed in a Clementian crusade of "fire exclusion." The "Ten-a.m. Policy"[3] for containment along with the unwavering commitment to limit the number of fires and acreage burned, suggested a resolve rooted in a missionary zeal to rid forest and other wildlands of the chaotic disturbances originating in "demon fire." Fire prevention propaganda from the 1920's to the 1960's emphasized fire as a destructive agent. This system of thought contradicted the experience of wildfire I had acquired while growing up in a fire-prone northern California community.

Only later did I realize the diversity of scientific opinion that obtained in land management agencies, and appreciate that early in this century agency leaders had begun to discuss the limitations of aggressive fire control policies informed by Clementian ecology (Schiff 1962). What appeared to outsiders to be monolithic opinion and commitment was increasingly a willful effort to construct and maintain explanations for wildfire that would enable their advocates to protect the integrity of their organizations and to maintain a political advantage. Knowledge, at first suppressed into the unconscious to protect "life's lie." must be contained by <u>deliberate</u> falsification (denial) when its eventual emergence threatens to undermine the superior position of an individual or organization (Bailey 1983). The politics of knowledge regarding wildfire was central in motivating me to study sociology and has remained a compelling interest.

[3]What is termed the "First Work Period" or "Ten-a.m. Policy" was developed to help dispatchers and fire managers determine the strength of attack that they should make on a forest fire to insure control regardless of economic considerations. The aim was to achieve control before the beginning of the next day's burning period--generally around 10 a.m. Failing this, action was taken to dispatch sufficient force to control the fire before the advent of the burning period of the following day.

Unlike Europeans. Americans, especially the honest, down-to-earth folk that tend to become foresters, are abhorred by the idea that denial of reality is a necessary part of everyday experience. Foresters who work for private industry have preferred to deny the contradictions expressed when defenders of free enterprise and unconstrained market processes seek government intervention and regulation when they can benefit from it. And only recently have government agency foresters begun to reveal the extent of their denial and, like their kin in the ministry, cultivated "cynical knowledge" to manage the contradictions inherent in institutionally transmitted belief systems. Goldner. Ritti and Ference (1977:539) use this term to "describe the understanding by members of an organization that presumably altruistic procedures or actions of that organization actually serve the purposes of maintaining the legitimacy of existing authority or preserving institutional structure."

A distinction between overt and covert knowledge (Bailey 1983), with skillful management of the latter by institutional gatekeepers, is as commonplace in land management agencies as in businesses, families and other ongoing forms of social organization. "Airing the dirty linen" or disclosing "skeletons in the closet" are met with reactions ranging from degradation rituals to loss of group membership through expulsion.

Control over covert knowledge is essential for maintaining group integrity and protecting opportunities to exercise power. Specialized knowledge, especially if clouded in technical jargon, or reports of extraordinary experience, tend to elicit deference from the unknowing. Phophets and futurists (and, in the Forest Service, econometricians responsible for FORPLAN) rely on such deferential behavior to legitimate their pronouncements. They are sometimes lucky, or influential enough to stimulate self-fulfilling prophesies, "proving" they are gifted with divine insight or exceptional sensitivity to hidden forces at work in society. But there is also another important way that the politics of revelation relates to the future.

A free society is characterized by the widely held norm that people have a "right to know." The responsibility for revealing covert knowledge has generally been assumed by the press. But increasingly, the public has itself taken an active part in revealing covert agency agendas through participating in planning processes. The National Forest planning process is clearly the most ambitious effort ever undertaken to respond to the interests of a wide variety of publics. When successful, forest plans become "social contracts" for inventing a future to be shared by the Forest Service and interested parties in society (Shannon. In press).

Laws and regulations guiding the national forest planning process provide citizens the opportunity to participate in the construction of agendas for future forest management. Although Forest Service officers retain ultimate decisionmaking authority, power is dispersed among citizen groups that exercise their right to know both what government agents are intending to do, how they will do it, and why these actions are justified. The most significant result of forest planning has been to reveal covert knowledge. Forest management decisions are now far more open to public inspection, democratic debate and compromise. A democratic, socially responsive planning process does not eliminate covert knowledge. It simply helps reveal any hidden agendas of management agencies without requiring competing interest groups to reveal their hidden agendas.

Democratization of national forest planning provides at least a partial answer to Ibsen's dilemma of how we can reveal our denials without suffering excessive cultural shock. Although many wounded Forest Service veterans might disagree, socially responsive planning has provided a compelling rationale for openly admitting imperfect knowledge and inviting a multitude of perspectives on how forest should be managed. Power sharing accompanies the admission of ignorance as well as the sharing of knowledge.

The Forest Service's attempt to conduct a socially responsive planning process, however, is contradicted by its simultaneous adoption of FORPLAN, a complex linear programming technique for rationally scheduling the production of forest goods and services. Since this technique uses a computer model to translate social values into economic measures that can be weighed for purposes of prescribing action, it inevitably necessitates the denial of experiences shared by interested publics. Even beyond the computer simulation technician's attempt to maintain the integrity of the "system" in the face of public criticism, willful manipulation of the assignment of economic values to predetermine allocation decisions has been a common practice of institutional gatekeepers--especially by the Reagan administration.

An understanding of the planning processes is essential for anticipating how the future emerges from the present. Such understanding will enable us to anticipate who is likely to be in positions to invent the future. Additional understanding of how ecological knowledge mirrors changing patterns of human community will help us to anticipate the direction in which these inventors of the future are likely to direct their thinking.

SOCIOLOGY OF ECOLOGICAL KNOWLEDGE

Ideals and Particularity in American Community

A commitment to an idealistic sense of national community is perhaps the principal reason Americans find it so difficult to accept the contradictions of daily life--including its inevitable denials of reality. National identity and political coherence stem largely from our Revolution and its institutional expressions rather than from common experience and social homogeneity (Frisch 1976). The latter bases of national solidarity, so important to the European nations to which we most often compare ourselves, have not connected individuals, groups, and the larger American society in an integrated whole. Social and political turbulence accompanied the settlement of a vast continent, waves of immigrants from diverse cultures, rapid geographic and social mobility, industrialization, and a bitter Civil War that brought industrialization to the entire nation. Americans have idealistically denied the reality of social differences, the particular groupings and identities that have given American society its richness and variety. We have until lately overlooked the reality of ethnicity, race, class, gender, and other forms of contiguity that are central to identification with particular communities.

The traditional American farming community, with the family and church at its center, has survived as a national ideal--enshrined in a make-believe world of sturdy yeoman farmers who constitute the "backbone of democracy." The fact that the traditional rural American communities are now almost nonexistent, and never exhibited the stability and endurance of their counterparts in other nations, has almost been swept from our national consciousness by our enthusiastic pursuit of ideals.

Consequently, we today find ourselves in a dilemma not unlike that faced by other revolutionary societies. Common identity, political coherence, and sense of contiguity are tied to the pursuit of political ideas and their institutional expressions. The Reagan administration was initially enormously successful in developing public support because it understood how ideological symbols serve as the source of our national community. The American Dream and the American Way are inspiring, powerful. and creative political ideals, both at home and abroad. Yet these ideals are also dangerous, delusive and destructive, since they deny the reality of an increasingly heterogeneous society with tremendous disparities of wealth, power, status, and cultural legitimacy.

Blind pursuit of our ideals has led us to blunder into wars where we destroy people in attempts to save them, school integration programs where we produce residential separation of the races in attempts to achieve racial balance, and social welfare policies where we institutionalize dependency on the state in attempts to make people more self-reliant. The law of unintended consequences haunts all who seek community in the global ideals of revolutionary transformation! Surely we are free from such self-deception in our attempts to control wildfire.

The tension between the pursuit of ideals and the realities of everyday living is as much a part of contemporary fire management as it is of war, racial integration, and social welfare. We already know how we conspired to deny the beneficial natural processes in our forest by attempting to control wildfire (Schiff 1962). But our pursuit of ideals continues uninterrupted. Two poles of community--idealism and social particularity--underlie contrasting fire policies and the biological theories that inform these policies. These two types of community are presently differentially expressed by two leading federal land management agencies. The National Park Service. U.S. Department of the Interior has leaned toward pursuit of an ideal "natural" ecosystem in which fire takes a course unconstrained by human intervention. In contrast, the Forest Service has, through its forest planning process, attempted to become more responsive to particular groups. interests, and communities. A comparison of these two expressions of community will help us to understand both how applied ecological thought has stemmed from social circumstances and where changes in the American community are likely to lead fire management in the future.

Contemporary Fire Management Issues

"Natural" Fire as a Ideal

To illustrate the persistent influence of idealism on our response to wildfire, I will focus on the National Park Service's attempt to reintroduce "natural" fire regimes into Sequoia-Kings Canyon National Park. Current National Park Service fire policy is permissive. Individual park units may develop approaches to managing wildfire that suit the park's objectives for perpetuating natural ecosystems and natural or cultural features. Sequoia-Kings Canyon has for over a decade been experimenting with prescribed burning in sequoia groves in an attempt to learn how to perpetuate these majestic giants. However, park scientists have recently proposed a change in their fire management policy (Christensen and others 1987). Rather than attempting to reproduce the low intensity ground fires described by early explorers, and attributed even earlier to the activities of Indians, Park Service scientists are considering the possibility of letting wildfire play a far more dynamic role in the sequoia ecosystem. Less frequent, more intense, and more destructive wildfire would be allowed so as to reproduce the "natural processes" that obtained prior to either European or Amerindian civilizations. Restoring fire to its "natural" role is expected to heavily char if not kill patches of large sequoias, as well as more shade tolerant species in the understory. This will create openings favoring widespread natural reproduction of sequoia.

The primary biological goal of this new policy would be to reintroduce the "natural" disturbances that were thought to occur before human occupancy. Expression of this alternative ignores the tremendous uncertainty regarding past fire frequency, intensity and effects--with the impossibility of ever knowing enough about past climate and vegetation to mimic "nature" (Brubaker 1987), to say nothing of influences from contemporary "unnatural." irreversible atmospheric changes in the biosphere. Because of its unusual emphasis on "natural process," this proposal offers an outcropping from which to interpret underlying social and cultural structure.

The pursuit of "nature," uninfluenced by human activity, is an idealistic expression of national community that predates our Revolution. In its earliest expression, humans were included in "nature," and what was sought by American colonist in our venture "into the wilderness," was a kingdom where human sin and wickedness were left behind (Bellah 1975). The boundary of this national community has shrunk, now including only those who understand and respect "nature" well enough to serve in her sanctuaries as priests or their acolytes. Yet, like all such idealistic communities, its sustenance is drawn from the hope or expectation of a period of great harmony (including "natural" harmony) and freedom from human greed, avarice, and competitiveness--in short, a millennium. And, correspondingly, it must aggressively defend itself against the realities that are inconsistent with these ideals by denying both the arbitrary secular religious origin of its vision and the impracticalities of its implementation.

Although the National Park Service goal of "natural process" incorporates a role for periodic catastrophe unacceptable to earlier Clementian ecologists, it stems from the tradition of idealism and management elitism that informed earlier ecological doctrine. A brief historical review of this doctrine will illustrate both the continuity in ecological thought and its sociological roots.

Clementian ecology grew out of a long tradition of Germanic idealism in which organismic functioning was imputed to supra-individual entities such as "society" or "nature." It was assumed that stability in such "organisms" was a natural product of equilibrium-seeking processes (Schiff 1966). Clements was most immediately influenced by social science idealists such as Roscoe Pound, and two sociologists, Herbert Spencer and Lester Frank Ward (Tobey 1981). Clements drew upon Ward's terminology for an organism-like society to describe ecological processes, and imputed ontological status to vegetative associations--vegetative "formations." A stable climax was assumed to inevitably dominate the "natural landscape" (Schiff 1966). All successional stages leading up to this climax were "imperfections" in the natural order.

But to fully understand Clementian doctrine, we must look for its roots in society. Its American intellectual origin was in "the genteel tradition" of the late nineteenth-century middle class. "Idealism" was defined by a belief in the "existence of nonmaterial or nonnaturalistic standards of quality, such as beauty, independent of human mind but recognized only intellectually" (Tobey 1981:32). Two of its primary spokesmen were Alexander Agassiz, a zoologist and engineer at Harvard University and Joseph Le Conte, famed University of California geologist. Their ideas were essential for understanding the continuity of thought found in fire management.

According to Tobey (1981), Agassiz rejected Darwin and advocated a catastrophe theory to explain the origin of the earth and its life forms. Geologic history was seen as a "succession of paleontological forms" interrupted by catastrophes that destroyed flora or fauna, with the deity creating life anew at the beginning of each epoch. (Echoes of the phoenix!) However, Le Conte adopted a gradualist view of God's creation, with emphasis on the <u>process</u> of divine creation rather than the act. For both Agassiz and Le Conte supernatural "ideals" were to be discovered through their manifestations in nature. (Now we have found company for the romantic idealism of John Muir and his reflections of the divine spirit in nature.)

But we have also discovered historical parallels, if not antecedents, for an emphasis on "natural processes" in national park management. After years of struggling to contain wildfire in the realm of reason and science, it appears to have escaped to again become an "act-of-God"--even though the toy of a playful God whose wrath has been tamed by a Marana course in anger management! I urge you to study the rational, scientific justification for a possible policy change at Sequoia-Kings Canyon National Park before dismissing my interpretation as the hallucinations of a demented sociologist. You will find that belief and its accompanying denials are far more prevalent than scientific proof.

This legacy of idealism has found continuing expression in a tradition of public land management in which scientifically trained experts planned society. The natural environment, like society, was perceived in terms of the people as a whole, not particular groups, classes or communities. Individual initiative and competition are outside the bounds of this "natural community" (Bellah 1975), and are to be discouraged, if not deliberately denied (Schiff 1962). Clements was so troubled by the destruction of the prairies that he rejected the legitimacy of the individualistic and competitive society and advocated the concentration of authority in the hands of experts (Tobey 1981).

Park Service fire management policy has perpetuated this tradition by minimizing opportunities for individual citizens and social groups to participate in deciding how parks should be managed. It is presumed that science will be a sufficient guide for future action, and that the diversity of particular values found in society is not a legitimate basis for building vegetation management plans.

Responding to Particularity as an Antidote for Institutionalized Disaster

The Forest Service has taken a different path by adopting a socially responsive planning process in combination with scientific expertise incorporated in interdisciplinary teams. As a result, a creative tension was established between particularistic and idealistic forms of community. The goals for resource management are informed by involving a wide variety of publics early in the planning process. The feasibility and efficiency involved in reaching these goals are evaluated by technical experts. As part of forest management, wildfire is treated as a plan-governed event--with the goals of fire management derived from the interaction of diverse communities of interest Rational, plan-governed fire management is new to the Forest Service. It originated in the early 1970's following three-quarters of a century of fire suppression activity dedicated to reducing the role of fire as a catastrophic event. Clementian notions of ecological succession and stable, fire-free climaxes were ruling theories during most of this period (Schiff 1966). Although the intellectual roots of Forest Service fire policy resembled those of the Park Service, a sociological dynamic that sustained fire suppression was far more pronounced in the Forest Service. This dynamic was integrally related to the creation and maintenance of an idealistic national community.

The establishment of organized governmental fire suppression early in this century was accompanied by public information campaigns. Efforts were made to convince the public at large that fire was destructive and should be eliminated from forests wherever possible. Aside from minor attempts to target communications on particular publics, emphasis was placed on the creation of a national community of concerned citizens who would cooperate fully with the fire suppression agencies. Both Pyne (1982) Lee (1977) have traced this information campaign from the late teens to the 1960's, and noted its phenomenal success as a public relations effort. However, a new interpretation of this campaign sheds light on how it sustained fire suppression policies and practices.

The United States is a revolutionary-based society that continues to depend on an idealistic national community for social coherence. It lacks the stability found in homogenity and long-shared traditions. Periodic crises may be needed to produce the social cohesion essential for maintaining the society. Barkun (1974) suggest that such societies periodically invent disasters to restore the widespread sense of group solidarity and emotional excitement to which the people trace their common origins. He quotes the psychologist Robert Lifton's comments on the Chinese Cultural Revolution: "it has meant nothing less than <u>an all-consuming death-and-rebirth experience, an induced catastrophe together with a prescription for reconstitution of the world being destroyed</u> (Barkun 1974:208, original emphasis). We are reminded immediately of the phoenix, and of Alexander Agassiz's views on successional progress in the natural world. Was Agassiz's thought process simply mimicking the social dynamics of a revolutionary society? And are National Park Service scientists at Sequoia reflecting a contemporary societal need for invigorating disasters? But before I jump ahead of my story, let me suggest that this dynamic was perhaps best represented by fire suppression in the Forest Service.

Remember that the Forest Service and other wildfire suppression agencies first invented "demon fire" to symbolize the ever-present threat. Continued vigilance was required in face of the threat, and immediate mass mobilization was the habitual response to a wildfire. The construction of a national community that would respond in unison to the cues of centralized fire control agencies was completed during World War II when the Wartime Advertising Council issued a propaganda campaign under the slogan "Careless Matches Aid the Axis." Smokey-the-Bear and the association of wildfire with Cold War threats sustained this vigilance until the late 1960's.

Periodic wildfires, with numerous major disasters, reinforced the coupling of disaster and social solidarity. A permanent revolution was institutionalized; evil (the fire demon) must be destroyed so that a new order (world) could be created (Barkun 1974). "And if evil remains, that only means we have been inefficient in destroying it. We must try again" (Barkun 1974:210). Doesn't this remind us of what Pyne (1982) described as the "Heroic Era" of fire suppression? These parallels of idealistic thought, national community and social action offer intriguing hypotheses for future investigation.

We also need to remember that the Forest Service took the initiative to change its wildfire suppression policy. Social solidarity and disaster were at least partially decoupled, and a surrogate for mass mobilization was discovered in a socially responsive planning process. Social connectiveness was rediscovered in particular communities and interest groups. But, more importantly, the interaction of these groups in the planning process yielded an appreciation for civility and mutuality--the basic ingredients for building a society stabilized by the respectful interaction of particularistic communities. This cooperative approach to planning was to a large extent inspired by the ideal of small-town democracy and the weaker rural tradition of particularistic community. Does the planning process contribute to the construction of a society that will not need periodic wildfires, wars, or other disasters to hold it together?

Community Fragmentation and Cooperation

The idealistic sense of national community weakened substantially during the 1960's and 1970's in response to growing citizen dissatisfaction with large public and private institutions. Awareness of an environmental crisis and the tragedy of the Vietnam War sapped legitimacy from private corporations and the government. A series of faultering Presidencies signified a loosening of the national societal fabric. And the Reagan administration has recently been less than successful in rebuilding an idealistic national community--despite its attempts to invent evil forces in the world. Fragmentation in the national community is well underway.

Yet, despite such fragmentation, our society is not dissolving. Compensatory processes are at work to fill the void left by shrinking national purpose. We appear to be entering an era in which social cooperation will become far more important as a source of stability. This trend is exhibited by a greater sense of partnership between government and industry, a willingness for sharing and cooperation among competing interest groups, and a reidentification of citizens with the stabilizing mediating structures found in churches, neighborhoods, extended families, and voluntary associations (Berger and Neuhaus 1977). I have already noted how forest planning processes can result in social contracts--agreements among particular groups and a government agency for predictable management of a given tract of forest land. In my own state of Washington, long warring timber, fish, game, and environmental interest groups have recently solidified an agreement to cooperate rather than continue fighting over State regulation of forest practices. What do these trends portend for fire management?

CONCLUSIONS

The contrasting cases represented by Park Service and Forest Service fire management point toward a fork in the path, which we will reach by the year 2000. Rather than choosing one direction over the other, we will most likely find ourself in new territory recognizable by the signs articulated in this paper. But we will need to suspend our inherited make-believe worlds long enough to read these signs and recognized where we are. And, if I have been successful in describing these signs, we will know where we are because we will be able to recall where we have been and will correctly interpret signs of continuity and change.

We may find a firm sense of national unity brought about by mass mobilization necessary for fighting a popular war or for repairing the biosphere following a global environmental disaster. These social conditions are likely to favor centralized authority for fire management, with responsibility for defining both ends and means delegated to scientifically trained experts. Since science can tell us little about where we should be going, but much about where we have been (Medawar 1982), we are likely to perpetuate institutionalized disaster--either in the heroic form typified by aggressive fire suppression or in the ritual of symbolic recreation of ecosystem (world) integrity through planning "natural" disturbance events. But we will have to watch carefully for the vengeance of "false gods" when we find ourselves attempting to invent either of these two forms of disaster to compensate for the loosening of a national sense of community. Playing "God" with wildfire may anger competing "gods" found in a society where a plurality of social groups increasingly share authority for directing fire management.

Alternatively, we may read the signs and discover our nation has escaped popular wars and environmental disasters, and is searching for social contiguity found in particularistic community. Fire management is likely to have become more pluralistic in its goals and approaches. It is likely to be seen as a tool for creating or enhancing resource values sought by a wide variety of social groups. Fire managers are likely to be trained to facilitate, mediate, and generate agreement among competing communities of interest. They would no longer be the scientific experts who decide both what is in the interest of the society and how it should be achieved. They would turn to experts for answers to questions of biological possiblility, economic feasibility and social acceptability in order to become more responsive to a pluralistic society.

I am not a prophet and can not see into the future. And, I don't trust anyone who claims such knowledge. But if I had to guess what fire management would be like after the year 2000, I would opt for the scenario built on the assumption of community fragmentation--perhaps because I find hope in this possibility. It would enable us to examine our "life's lies" without generating nihilism. And, as a result, we would be more likely to learn how to substitute self-restraint for the invention of disaster. This would make us wiser resource managers.

But I am also a realist, and having watched 46 years of human folly unfold before my eyes. am drawn again to the lines of T.S. Eliot:

> What we call the beginning is often the end.
> And to make an end is to make a beginning.
> The end is where we start from.

REFERENCES

Bailey, F.G. 1983. The Tactical Uses of Passion: An Essay on Power, Reason, and Reality. Ithaca, NY: Cornell University Press. 275 p.

Barkun, Michael. 1974. Disaster and the Millennium. Syracuse NY: Syracuse University Press. 246 p.

Bellah, Robert N. 1974. The Broken Convenant: American Civil Religion in a Time of Trial. New York: The Seaburg Press. 172 p.

Berger, Peter L; Neuhaus, Richard J. 1977. To Empower People: The Role of Mediating Structures in Public Policy. Washington DC: The American Enterprise Institute. 45 p.

Brubaker. Linda B. 1987. Vegetative history and anticipating vegetative change. Paper presented at Ecosystems Management Workshop; College of Forest Resources, University of Washington; 1977 April 6-10.

Christensen, Norman L; and others. 1987. Review of fire management program for sequoia-mixed conifer forests of Yosemite, Sequoia-Kings Canyon National Parks; Final Report. 37 p.

Frisch, Michael. 1976. Social particularity and American culture: two-edged sword of community. In: Gilman. Sander. ed. The City and Sense of Community. Itahaca, NY: Center for Urban Development Research; 32-37.

Goldner, Fred H.; Ritti, Richard R.; Ference, Thomas P. 1977. The production of cynical knowledge in organizations. American Sociological Review 42(4): 529-551.

Lee, Robert G. 1977. Institutional change and fire management. In: Mooney, Harold A.; Conrad, C. Eugene. tech. coords. Proceedings of the Symposium on Environmental Consequences of Fire and Fuel Management in Mediterranean Ecosystems; 1977 August 1-5; Palo Alto, CA. Washington DC: Forest Service, U.S. Department of Agriculture: 202-214. General Technical Report W0-3.

Medawar, Peter. 1982. Pluto's Republic. New York: Oxford University Press 351 p.

Pyne, Stephen J. 1982. Fire in America: A Cultural History of Wildland and Rural Fire. Princeton, NJ: Princeton University Press. 654 p.

Schiff, Ashley L. 1962. Fire and Water: Scientific Heresy in the Forest Service. Cambridge, MA: Harvard University Press.

Schiff, Ashley L. 1966. Innovation and administrative decision making: the conservation of land resources. Administrative Science Quarterly 11 (June): 1-30.

Shannon, Margaret A. In press. Citizen participation in land management planning: the formation of a social contract. In: Lee, Robert G.; Field. Donald R.; Burch, Jr., William R. eds. Community Forestry: Continuties in Natural Resources Sociology. Boulder: Westview Press.

Tobey, Ronald C. 1981. Saving the Prairies: The Life Cycle of the Founding School of American Plant Ecology, 1895-1955. Berkeley: University of California Press.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

The Intrusion of Human Population Into Forest and Range Lands of California[1]

Ted D. Bradshaw[2]

Abstract: Demographic and economic growth are pushing deeper into California's forest and range lands, making effective fire protection and traditional industrial uses of the land more difficult. Urban forces that will increase the difficulties in the future include: increasing urban population pressures, selective migration, low-priced housing, adequate infrastructure, decentralized development, and government inadequacies. Some compensating trends that will tend to restrict growth and minimize problems include a near-term weakening of the rural economy, few major planned developments, growth opposition, more integrated recreation uses, zoning for larger parcel sizes, and stabilization of tax benefits such as the Timber Production Zone.

The nature and pace of demographic and economic development significantly affects California's forest and range region (Bradshaw, 1986). In general it is useful to think of this growth and development along a continuum bounded by two value sets, stretching from the natural wildlands to the developed urban setting (Blakely, 1984). The line is not sharp between these two patterns, but with urban development comes an inexorable pressure limiting the effective management of natural resources. This pressure is evident in both fire protection and the management of land for industrial purposes.

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The patterns of growth that continue to shape the intrusion of people and urban values into rural lands can be organized according to whether they are generally antagonistic or favorable to the effective management, biological growth, and economic well being of the state's forest and range resources areas and industries. Problems from the perspective of forest management and fire prevention/suppression are defined as those conditions or practices due primarily to growth in rural areas that:

--restrict the land available to productive management,
--limit the range of effective management practices used on productive land, and
--lead to the allocation of investment dollars or natural resources away from productive forestry or agriculture.

On the other hand, favorable developments from the point of view of forest and range resource management include those that preserve available land from alternative patterns of development and that mitigate the negative effects of growth on the management of natural resources.

PROBLEMS OF GROWTH FOR FOREST AND RANGE MANAGEMENT

The critical problems caused by growth in the forest and range regions of the state are (1) the continuing increase of population in and near forest and range areas. (2) the people moving into forest and range areas are self-selected to include a high proportion of people who value the open space and rural life style of the region even at the expense of economic opportunity. (3) considerable long term population growth will be stimulated due to low price rural housing and unbuilt subdivisions, (4) inadequate infrastructure capacity seems not to limit rural and forest region growth, (5) many small independent developers rather than a few large ones are building in rural areas, making it more difficult to monitor growth and to control cumulative impacts, and (6) the inability of local government to effectively balance the needs of the forest and range industries with public concerns over management practices and industrial impacts.

Rural Population Growth Exceeds Urban Growth Rates

The first source of strain on rural forest and range area management is that growth is likely to continue at a rate exceeding most urban areas (California Department of Finance, 1983). The counties with the largest forest and range resources are now growing at a rate about 20 percent faster than the urban counties, with the small foothill counties still the predominant population growth rate leaders in the state. Although the rural population increase has slowed since the 1970s when it was growing three times as fast as the urban counties, population growth in the forest and range counties continues to exceed urban population growth and will probably continue to do so past the turn of the century. Whereas the state as a whole has experienced a doubling of its population every 20 years since statehood, California will not again double its 1970 population of 20 million until at least 2020, a period of 50 years. However, by 1986 eight counties had already doubled their 1970 population, and these counties were all in the forest region: Nevada, Lake, Alpine, El Dorado. Mono, Mariposa, Calaveras. and Amador. In addition, seven counties, all of which were forest except one, had at least 75 percent of the population needed to double, and they might be able to do so by 1990, a period of 20 years: Tuolumne, Madera, Riverside, San Luis Obispo, Placer, Trinity, and Santa Cruz.

The continuing pressure of high population growth rates on the counties that include the major forests and range lands of the state inevitably means that there are more people who want land to develop, who want to use roads, and who have a stake in the management practices used on the land near where they live. While this fact does not necessarily lead to predictions about whether newcomers or oldtimers will be involved in activities that restrict traditional resource industries or at what level of population growth pressures will be felt, experience has shown that with more people comes a higher probability that a conflict will result (Beale, 1975).

Newcomers Seek to Preserve Rural Environment

The people moving into rural areas are self-selected to be similar in many respects to the people who have traditionally been residents of the communities into which they move. For example, they value the amenities of rural living and they want a small town atmosphere. They generally have left the city because they want to avoid the congestion and problems found there. When they come to a rural community they do not want it to become urbanized too fast, and they want to preserve the surrounding natural environment (Bradshaw and Blakely, 1981). However, for the most part the newcomers do not make their living from the land and they do not understand or appreciate the values of those who do. Consequently. they more often seek preservation and oppose major industrial intrusions.

This self-selection of newcomers is reflected in the types of communities into which they move. The most rapidly growing communities are those with a strong tourist base and those with large numbers of elderly and retirees. Tourist communities for the most part rely on an attractive environment and nearby recreational or historical attractions, leading to pressures to maintain attractive surroundings. Retirees move to rural communities looking for inexpensive, safe, and attractive places to live. This group tends to be financially secure under social security, and contributes significantly to the overall economy through their expenditures (Hirschl and Summers. 1982). Newcomers to professional and trade centers, as well as manufacturing towns, contributed to moderate growth rate, while government centers and agricultural communities were the slowest growing. Moreover the growing places have populations with higher incomes, less poverty, fewer minorities, and higher levels of education, reflecting a population that is both more capable of developing their own jobs in the rural environment and more interested in a dispersed urban style of life within the forest and range region (Bradshaw, 1986).

Due to this selective recruitment of essentially middle and upper middle class persons into growth areas that also have high degrees of dependence on traditional forest and range industry operations, misunderstandings and opposition to some industrial practices occur. For the most part the newcomers are not dependent upon the traditional industries of the areas for their income, and in fact they often view these industrial activities counter to their interests (Bradshaw and Blakely 1979).

Low Priced Rural Housing and the Acceptance of Mobile Homes Attract Development

The lower price of housing and land in rural areas contributes to the expansion of the population base. Housing in the forest and range areas cost 25-50 percent less than comparable housing (Bradshaw,1986). In a large number of the most rapidly growing areas, a high proportion of households live in mobile homes. Moreover, the greatest population growth has been in areas with high levels of housing vacancies, reflecting in part the potential of converting seasonal homes to permanent residences. The price of California urban housing is among the most expensive in the world, leading to an ongoing demand for lower priced rural housing.

In addition, lots that were subdivided years ago carry the potential for considerable unregulated expansion. Thousands of lots (how many is not known) remain unbuilt in subdivisions created as early as the 1920s and 1930s. The major barriers to construction are still the high cost of all construction, especially for second homes, and the problems of connecting the lots to water and sewage systems. Increasingly, local planning departments also place strong requirements on these parcels for adequate construction, which is often expensive in rural areas.

However, if an owner wants strongly enough to build and has the financial resources to do it, there are few means available to local communities to stop or slow the development of these lots. One type of tool is the establishment of a maximum number of building permits that can be issued each year, such as Santa Cruz and Napa counties have done. But this level of antidevelopment initiative is relatively unlikely in most rural counties with large numbers of unbuilt parcels, and consequently they provide a considerable potential for growth outside the zoning process.

Infrastructure Limitations in the Long Run Will Not Stop Rural Growth

Many forest and range communities are near capacity on sewage connections or are expecting to reach capacity soon. For the most part, however, only a few communities have restricted development because of inadequate capacity, and most of these communities had inadequate systems in the first place. While it is increasingly difficult to finance improvements, inadequate capacity will not be a long term barrier to development, with just a few exceptions. Similarly, water problems are faced by many rural communities, but supplies are nearby and probably can be delivered at reasonable (though increased) prices (Bradshaw 1986).

Incremental Small Scale Development May Be Harder to Identify and Control Than Large Single Owner Developments

The major form of land development in the forest and range areas is on single parcels or in a small number of parcels being developed individually by local developers. While large lumber and land development companies initiated huge subdivisions in the 1960s and early 1970s, often near new reservoirs, this form of development has largely subsided. Instead the largest impact is from the cumulative consequences of thousands of individuals building on previously unoccupied parcels of land distributed throughout the forest and range land, often outside community boundaries. The major techniques available to local governments to control growth are disproportionately effective on large concentrated developments. The techniques of anticipating and mitigating problems associated with the cumulative impact of many small parcels is not well understood. This problem is being faced by Vermont where an effective strategy for dealing with large developments has been threatened by the overwhelming consequences of many small ones (Healy and Rosenberg 1978).

Local Governments Are Unlikely to be Able to Resolve Conflicts

Local governments are in a difficult situation with regard to the strains of growth pressures on the one hand and the need to preserve the traditional industries and way of life for the long-term population. Local government lacks the capacity, tools, and will to meet the challenge in many localities, making ongoing problems more severe (Blakely and Bradshaw 1985).

Growth has concentrated along major highways in the forest and range areas of the state, and these are often the same roads used for the largest amount of truck traffic. On small roads nearer to the forest, complaints about trucks are often heard from the growing resident population. Yet this mainstay of the forest industry remains a growing problem in small communities.

Intensive forest and range management practices are criticized. Local concern over population growth carries over to concern by local groups for management practices on nearby private and public land. Since amenities of the natural environment are the major attraction of people to rural areas, major resistance is expressed at times to patterns of resource management that involves harvesting trees and using herbicides for brush control. Local people are aware of their interdependence with the land and are concerned about the air and water quality associated with forest and range management practices nearby. Maintaining the viewshed causes a more difficult problem in many respects especially for the large tourism industry.

FACTORS FAVORABLE TO MODERATE POPULATION GROWTH AND EFFECTIVE RESOURCE MANAGEMENT

The slowing of population increases and the greater separation of population and forest activities compensate for and counterbalance the factors likely to reduce the effective utilization of forest resources in California. The following factors are most important in this respect: (1) the long term outlook for economic growth in the rural areas is that it will not repeat the very high rates of the 1970s, (2) few major industrial, residential, and recreational developments are being considered, (3) residential growth and commercial development is frequently contested and stalled, (4) recreational resources are being developed in conjunction with forest and range management programs, thereby reducing conflict, (5) new zoning provisions offer greater protection to forest and range land from competing uses, and (6) the land set aside by Williamson Act and the Timber Protection Zone (TPZ) tax programs seem to be stable.

The Rural Economic Base is Weakening from the 1970s

Several aspects of the expansive economic growth in rural areas during the 1970s have weakened, leading to projections of less economic vitality in rural communities in the 1980s and beyond. This weakening of the economy is not good news for many rural communities, but it does slow the pressures of growth. The slowdown in the amount of Federal money going to social programs seems to be a critical component of this process. In the 19709, based on perceptions of lagging rural economies and extensive poverty, Great Society programs expanded to meet the true needs of rural residents, and for the first time rural components of programs were developed to match the delivery expectations of the program's urban counterpart. Government cutbacks have occurred throughout the country, and rural programs are no longer the source of special attention, limiting this source of rural growth (Blakely and Bradshaw 1985).

The major source of California's economic development in the 1980s is the huge increases in defense expenditures. These have gone largely to urban defense contractors while less decentralization into rural areas has been possible. High technology firms associated with the growing consumer electronics industry made a significant contribution to rural economic growth in the 1970s (Bradshaw and Blakely 1979). However, even this industry is under severe competitive pressures and is not expanding much in the 1980s.

Equally important, local government employment and social service employment funded by state and federal sources have not kept up with the overall pace of the economy. During much of the 1970's these programs constituted a transfer from urban areas to less developed rural places, providing employment for skilled persons working in organizations capable of obtaining federal grants.

The private sector has also lagged in its move to rural locations. Manufacturing plant relocations, which have not been particularly important in California's rural counties in any case, no longer are a potential source of new rural jobs. Many service industries are automating and no longer need rural work forces. The bulk of rural economic growth is in small business, as it has been for the last several decades. However, the present rural economy seems to be entirely dependent on small businesses whereas they were only partially dependent on small business previously.

Commodities continue to weaken as a component of the rural economy. Agricultural exports are a problem throughout the nation, with many "third world" countries reaching self-sufficiency in basic grains. Beef and lambs, major range products, suffer from declining domestic markets and foreign competition. Lumber imports continue to threaten the local lumber industry as well.

These patterns, though only preliminarily identified, suggest caution in the projections for rural economic pull in the future. The prognosis is not for major rural depression, but only for a slower future economic growth.

Few Major Industrial, Residential, Residential, end Recreational Developments are Being Constructed

Several new industrial facilities with 100 or so employees are being considered, but larger ones are not. As well the proposed facilities are often deeply contested, as evidenced by the large public outcry over the construction of biomass energy plants in several rural locations.

Growth is Being Contested and Frequently Stalled

The pressure for local areas to closely evaluate and monitor the growth taking place is widespread. In about half of California's counties, growth is deemed to be visible and contested, and in these situations local groups are formed and opposition is focused on the planning process to slow the rate of development.

Better Integration of Recreation and Forest Management.

New state laws that provide mechanisms whereby forest and range land owners can charge fees to hunters and other recreational visitors on their land provides another opportunity for effective land management that produces an economic return. Landowners receiving income from these sources neutralizes some of the negative consequences of expanding recreational pressures on rural lands with little compensation to landowners whose property provides necessary habitat for wildlife.

Zoning for Larger Parcel Sizes

Over half the counties in California have taken steps within the last 5 years to increase the minimum parcel size of forest and agricultural land. These steps to use zoning regulations to slow the parcelization of rural land are a significant step in the direction of establishing more responsible county efforts to protect and solidify the forest and range industries and their land base. Supplemented by the taxation advantages of Williamson and TPZ contracts, forest and range parcels are now zoned closer to the sizes on which minimum industrial activity is possible. However, these parcel sizes are still questionable in terms of the minimum plot on which forestry or range management could be efficient and practical. Economical forest management may not be possible on parcels as small as 20 acres, and 500 acres or more may be required in many range areas. Zoning strategies that supplement the establishment of minimum parcel sizes are also being explored, including cluster zoning and use restrictions.

Williamson Act and Timber Production Zones are Stable

County planning directors report that few parcels under the Williamson Act or in TPZ taxation zones are being converted out of their plan and developed for alternative uses. While the coverage of these plans is not complete, most of the industrial forest land, and much of the other prime land is covered. The counties think that this land is a fairly stable base of resource dedicated property.

On balance, then, the growth pains that the forest and range areas experienced during the 1970s have eased on their own and have been countered by productive responses on the part of government and planning departments. These efforts have removed some of the most threatening problems faced by communities in the forest and range region. However, the reality remains that the forest and range areas are continuing to grow with more politically active and astute people, and they will make increasing demands on industry to mitigate the adverse effects of their of their operations

POLICY ISSUES

The relation between urban population growth and natural resource management poses significant questions for policy consideration at the state and local level. This review is not intended to be exhaustive, but to identify the most pressing issues.

1. Subdivisions. Progress has been made in developing better methods to monitor and control land splits and subdivisions, though any increase in the number of parcels in rural communities poses the potential for major increases in the population living there. The cumulative effect of many land splits which are not built upon for years is a major concern, yet the rationale for constraining land divisions is not entirely well established. The subdivision of land into five or more pieces is well controlled by laws governing subdivisions, but divisions into four or fewer pieces is not. These smaller splits should also be more closely monitored.

Existing subdivisions pose an even more difficult challenge to effective planning. Many lots in Lake and Nevada counties were created before standards were established for minimum size and before adequate infrastructure was budgeted. Today, these lots are legally developable if infrastructure could be provided and if an appropriately designed building was proposed. If they were all developed, however, they would overload the communities in which they exist, stressing schools, roads, utilities, and police/fire services. Some planning departments are putting pressure on owners to combine and swap lots to bring them into conformity with modern standards, while others are simply waiting until the issue becomes critical. A number of communities have explored purchasing development rights on some parcels, but this has usually proven very expensive. For rural communities and the owners of these parcels, a better solution needs to be reached.

2. Zoning policies. County zoning revision efforts to increase minimum parcel sizes within productive agricultural and forest land zones need to be continued. The effort to set minimum size land parcels of 5 to 20 acres in forest and range areas can effectively reduce the density of population in areas that have ample natural resources. Too often, however, small parcel sizes allow the land to be taken out of production while the parcels sell at higher prices to more affluent outsiders who use the land for a "ranchette" or other nonproductive use. The progress being made by in increasing the minimum parcel size within forest and agriculture zones to areas that constitute large enough economically viable parcels is a significant contribution to the protection of the forest and range resource, within the goals and objectives of the local community. Innovative and effective strategies such as cluster zoning or a "rural planned development" (RPD) permit residential development on small parcels situated on the least productive part of the parcel, with the remainder protected by deed as a single large agricultural parcel. Counties with forest and range lands should examine their zoning rules and use appropriate strategies to protect the natural resource areas where productive forestry or ranching are desired.

Moreover, land in these zones and neighboring zones should have the expectation of productive uses, avoiding questions of many challenges now faced by landowners about whether they can harvest on their property. Similarly, land in these zones should not be open to speculative valuation for residential or commercial development. In short, the planning process as it is currently practiced is an attempt to adjust the expectations of owners about what can and should be done on their land to the overall preferences of the public for the long term development of their community. To the degree that the planning process continues to offer unclear or contradictory mandates (such as to zone forest land in parcels as small as 5 acres each), the expectations of landowners can not be stabilized. Similarly, if changes and exceptions to the general planning process are frequently made, the expectation that the plan will hold would be appropriately questioned.

The pressure of population growth itself (as well as technological changes in transportation, industry, and forest management) contribute to the uncertainty of the planning process. A major policy crisis faced by the traditional zoning process is how to remain flexible to accommodate unforseen opportunities and to correct unforseen problems, while at the same time remaining fair and consistent. Significant progress has been made in solving some of these problems through the use of performance zoning criteria, which place low emphasis on the geographic allocation of land and emphasize the identification and mitigation of impacts of land use changes.

3. Research and development. The California Department of Forestry and the

University of California need to develop new fire protection. logging, and range management practices that are more compatible with a growing urban population near traditional forest and range properties. A major criterion for establishing management programs and for developing research programs should be the minimization of effects on the nearby urban population. In the long run forestry, lumber, and range industries will have to be compatible with nearby urban populations. The necessary research and demonstration programs to ease the interface problems should be initiated now.

4. Property rights issues. Property rights, ironically, emerge as a critical factor in these debates. On the one hand, the exercise of strong controls by the public over land use to control the rapid infusion of population into areas near the forest is an advantage to forest interests. At the same time, these same controls can be used against the forest industry to regulate their forest practices and to control the disposition and use of their land. It is unclear whether the benefits to the public and the industry are now in balance, or whether one group is giving more than it is getting.

Population growth in the forested and range areas of California is a mixed blessing. On the one hand it is essential to keep the small rural community from becoming a rundown, hopeless place. On the other hand, population growth brings change and pressure that conflicts with the traditional ways of life and sources of employment. Fire protection and management practices will need to accommodate the social and economic changes that are shaping California's forest and range areas. Programs are needed to reduce conflict and to identity and implement strategies that will be of mutual benefit. The tools for this accommodation are available but must be used creatively.

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REFERENCES

Beale, Calvin L. 1975. The Revival of Population Growth in Nonmetropolitan America, Washington DC: ERS-605. U.S. Department of Agriculture. Economic Development Division, Economic Research Service; June.

Blakely. Edward J. 1984. New People in the Woods. In Bradley. Gordon A, Land Use and Forest Resources in a Changing Environment, Seattle: University of Washington Press.

Blakely, Edward J.; Bradshaw, Ted K. 1985. Rural America: The Community Development Frontier. In Fear, Frank; Schwartzwaller. Harry, eds. Research in Rural Sociology and Development, Vol 2, New Jersey: JAI Press. Inc.

Bradshaw, Ted K. 1986. Social and Economic Development in California's Forest and Range Lands. Berkeley: University of California. Institute of Governmental Studies, mimeo.

Bradshaw, Ted K.; Blakely, Edward J. 1979. Rural Communities in Advanced Industrial Society, New York: Prager.

Bradshaw, Ted K.; Blakely, Edward J. 1981. Resources of Recent Migrants to Rural Areas for Economic Development: Policy Implications. Berkeley: Cooperative Extension Service. University of California; September.

California Department of Finance. Population Research Bureau. 1983. Population Projections for California Counties, 1980-2020, with Age/Sex Detail, Baseline 1983. Report 83-P-3 Sacramento; October.

Healy, Robert G.; Rosenberg, John S. 1978. Land Use and the States. Washington DC; Johns Hopkins University Press.

Hirschl, Thomas A.; Summers. Gene F. 1982. Cash Transfers and the Export Base of Small Communities. Rural Sociology 47(2): 1982; 295-316.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Urban-Wildland Fire Defense Strategy, Precision Prescribed Fire: The Los Angeles County Approach[1]

Scott E. Franklin[2]

Abstract: In the County of Los Angeles, critical conditions at the urban-wildland interface range from concentrated development to dispersed development; elevations from sea level to 5000 feet with diverse ecosystems characterized by coastal sage scrub, Chamise, sumac, Ceanothus, Toyon, oak woodlands, pine forests, and desert sage; air quality impacts; sediment production; public education; and resource allocation.

The County of Los Angeles Fire Department has implemented a strategy to manage chaparral at the urban-wildland interface. The strategy encompasses historic wildfire frequency history and Santa Ana wind corridors coupled with scientific validation. Key to implementing this program has been the establishment of a Coordinated Resource Management Program.

Research requirements for the program are being addressed cooperatively by the Pacific Southwest Forest and Range Experiment Station, Forest Service, at Riverside, California. Participants in the "umbrella" agreement also include Angeles National Forest, Los Angeles City Fire Department of Public Works (Flood Control), National Park Service, and the California Department of Parks and Recreation. Of particular significance is the ongoing scientific research associated with the urban-wildland management strategy.

The Los Angeles County Vegetation Management Program evolved after the 1978 disasterous Kanan Fire. That fire consumed 25,000 acres in 3 hours traveling from the Ventura Freeway (Highway 101) to the Pacific Ocean, about 10 linear miles. Over 300 structures were lost.

The fire, pushed by 60 gusting to 80 plus miles per hour Santa Ana winds, burned through fuels that averaged over 20 tons per acre. During high intensity runs of the fire, over 100 acres per minute were consumed representing an energy release s that approximated the Hiroshima nuclear event.[3]

Recognizing that energy releases of this magnitude are impossible to combat with conventional wildfire suppression resources, the Los Angeles County Fire Chief impaneled an interdisciplinary task force to address this problem. The task identified the following:

1. Historic wildfire corridors using fire history maps dating to 1919.

2. Santa Ana wind corridors. These are areas where Santa Ana winds surface and impact communities down wind.

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[1]Presented at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

[2]Fire Captain and Vegetation Management Coordinator, County of Los Angeles Fire Department, California.

[3]Data on file, County of Los Angeles Fire Department.

3. Communities that are vulnerable to wildfire based upon fire history, Santa Ana winds, and fuel loading.

4. Areas that were experiencing development that in the future would be impacted by the above conditions.

5. Specific watersheds that, if burned under wildfire conditions, would pose a high sediment production capability.[3]

In the interim, between 1978 and 1980, the California Department of Forestry was seeking legislation to authorize burning on private lands and, most importantly, addressing the liability and environmental problems associated with a Vegetation Management Program.

The rash of wildfires in fall 1980, particularly the Panorama and Stable Fires, expedited this legislation. In 1981, SB 1704' became law providing the liability and environmental solutions to implement a program in State Responsibility Areas (SRA). There quickly followed a Statewide Coordinated Resource Agreement to allow cooperating agencies to burn on Federal lands as SB 1704 specifically precluded using State funds on Federal lands without quid pro quo on the part of the Federal agency involved (Resources Agency 1981).[3]

In 1984, the Los Angeles County supervisors unanimously passed a resolution creating the Los Angeles County Coordinated Resource Management Program (CRMP) The resolution named John W. Englund, Forester and Fire Warden and Fire Chief, "Lead Agent" for resource programs in Los Angeles County, in addition this resolution set the stage for all governmental agencies in Los Angeles County to cooperate in programs within their annual budget capabilities that are mutually beneficial and in some cases, exclusive to their individual interests.

Within the first year of the passage of the Coordinated Resource Agreement, the following agencies became participants: Angeles National Forest, Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; Los Angeles City Fire Department; Los Angeles County Department of Public Works; Los Angeles County Department of Parks and Recreation; Los Angeles City Department of Water and Power; National Park Service: U.S. Department of the Interior; Santa Monica Mountains Recreation Area; California Department of Parks; and California Department of Forestry and Fire.

The Los Angeles County Coordinated Resource Management Program (CRMP) has two unique components:[3]

1. The umbrella concept with provision for specific projects to be executed cooperatively through a simple work plan that spells out the benefits and responsibilities of each participant.

2. Research requirements addressed cooperatively through the Pacific Southwest Forest and Range Experiment Station and the University of California at Los Angeles. Specific scientific research is producing a product that addresses native shrub regeneration, fire effects, models for wildland-urban fuels and fuels structure, smoke management and air quality chemistry, and post fire impacts of flood/sediment and debris flows.

Since the Los Angeles County program is designed to mitigate the effects of heavy fuel loads adjacent to concentrated and dispersed development or literally to "burn under the eaves," precise fuels and weather information is mandatory.

The Forestry Division within the Prevention and Conservation Bureau of the Los Angeles County Fire Department has instituted a fuels moisture monitoring program, on a 2-week basis, year-round, that tracks live fuel moisture in the following shrubs: Ceanothus, Chamise, and sage. This information is shared with cooperating agencies.

In addition, before and during a prescribed burn project, pilot weather balloons are launched and tracked with a Theodalite. This information allows the fire manager to provide a precise burning prescription. The pilot balloon data is also shared with the South Coast Air Quality Management District to update that agency's local hourly wind flow charts.

Phil Riggan of the Pacific Southwest Forest and Range Experiment Station. in conjunction with Jim Brass of NASA-Ames Research Center is investigating the shrub leaf moisture content with infrared imagery. In 1985, two areas in the Santa Monica Mountains were impacted by wildfire that was diagnosed earlier in the year with low reflectance in the infrared bands.

The preliminary research indicates that there is a relationship between leaf moisture content and infrared reflectance values regardless of age class of chaparral. This could prove to be an outstanding management tool, particularly in stands of mixed chaparral.

As a result of the Lodi Coordinated Resource Project, whose participants include-the Pacific Southwest Forest and Range Experiment Station, Angeles National Forest, California Department of Forestry, and the County of Los Angeles Fire Department, preliminary data suggest that pollutants accumulated during decades of chronic exposure to urban emissions may be carried aloft during chaparral fires near the Los Angeles basin. Nitrogen and sulfur oxides in smoke from the experimental fire were as much as 300 times more concentrated than had been measured elsewhere according to Lawrence Radke of the University of Washington.

Wildfires frequently burn under the most adverse weather conditions including serious air pollution episodes. Where smoke is trapped near the ground, it may aggravate unhealthful air quality. Major wildfires may also inject nitrogen and sulfur oxides to heights in the atmosphere where they can be carried long distance, possibly contributing to acid rain in sensitive western ecosystems. This demonstrates the need for continued activity to break up large expanses of chaparral through the use of small, incremental prescribed burns, particularly in sensitive areas where chaparral and residential development are intermixed.

In comparison with major wildfires, lower intensity prescribed fires should volatilize less nitrogen or sulfur from soils and woody fuels and oxidize less atmospheric nitrogen to nitrous oxide. Further research is needed to better quantify emissions that may affect human health including the roles in smoke chemistry of accumulated pollutants and fire intensity.

Over the years, volumes have been written by research scientists, fire insurance specialists. engineers, and urban planning practitioners regarding urban encroachment into the wildlands.

Until the mid 1980's, all agreed that structure survival could only be accomplished through the following methods:

1. Structural Components
   A. Fire-retardant construction (roofs. eaves. etc.)
   B. Structure location (top of ridges, etc.)
2. Vegetation Conversion Component
   A. Total vegetation removal for 200 - 400 feet from structures
   B. Green belts, involving removal of native shrubs and substituting irrigated shrubs

In both the structural component and the vegetation component, fire officials have met with stiff resistance from both development and environmental interests. While some of the structural components have been accomplished, i.e., fire retardant roofs, little has been accomplished regarding structure location.

High altitude infrared imagery and on-site inspection show that green belts or cultivated biomass, after several years, appears to take on the characteristics of the adjacent native vegetation, i.e., significant amounts of dead fuel, and thus enhances the conflagration hazard particularly under severe fire weather conditions. Dealing with cultivated biomass poses a new problem in fire defense planning and will require considerable education from fire agencies and cooperation on the part of residents.[3]

Recognizing the impact of these diverse interests, the Los Angeles County Fire Department, under its charter function as the Department of Forester and Fire Warden, annually sponsors a symposium that affords an opportunity for research scientists, operational managers, and the public to exchange information on problems associated with managing chaparral fuels at the urban-wildland interface.

Since 1983, over 15,000 acres in 30 projects have been treated through the use of prescribed fire ranging from the communities of Castatic and Newhall in the North County, Bonelli Regional Park in the East County, Baldwin Hills in the South County, and Bel Air and Topanga Canyon in the West County.

In the interim, eight major wildfires have swept through areas that were under planning for the use of prescribed fire, thus validating the planning system. Four completed prescribed burn projects were instrumental in checking or stopping wildfires.[3]

Communities as diverse as Bel Air, Malibu, Topanga Canyon, Placerita Canyon, La Canada, Flintridge, and Castaic have requested prescription burn projects in their areas to mitigate the wildland hazard.

Recognizing the strong public support for the program, the Forester and Fire Warden and Fire Chief have, within the existing operational annual budget, instituted the following:

1. Within the Operations Bureau established the position of Vegetation Management Coordinator/Fire Defense Planner to oversee fuels reduction projects.

2. Established a fuels and weather monitoring unit within the Prevention and Conservation Bureau, Forestry Division. This is the only unit of its kind in the State of California.

3. Established within the Services Bureau a nationally recognized program for aerial ignition using fire helicopters, fire suppression camp personnel, and heavy equipment for implementing the projects.

4. Established within the Administrative Bureau, a Vegetation Management Training Program in cooperation with State and Federal agencies and actively recovered available federal, state, and local funds for the program.

Urban wildland fire defense planning, in Los Angeles County, under the direction of Fire Chief John W. Englund, has become a management program that reflects support from the fire service, the public, and scientific community.

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What Will the Wildlands Be Like in the Year 2000... Future Perfect or Future Imperfect?[1]

Carol L. Rice[2]

Abstract: Profound changes have taken place in the western wildlands during the 20th century that will have great impact on land management policy and operations. Wildlands are being developed. Reduction of fire has altered plant species relationships in terms of dominance and density. The number of ignitions will continue to increase. The trends unchanged will result in greater resource damages. Little can be done to stem the tide of encroachment into the wildlands and its attendant increase in human caused fires. Land managers can restore the balance of plant spcies [sic] as well as fuel accumulation only with sweeping management activites [sic]. Land managers will need to develop a wide power base among the public so the needed programs will be funded.

As this is a future-oriented paper, a review of the futuring process may be in order. The process of futuring requires one to first identify trends and then discover implications of those trends to develop a vision of what we would like to see in the future. By futuring one can develop an effective plan to change the probable coming events, and select preferred scenarios from the possible. The reader is also encouraged to keep in mind the words of George Eliot: "Prophecy is the most gratuitous form of error."

[1]Presented at the Symposium on Wildland Fire 2000, April 27-30, 1987. South Lake Tahoe, California.

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TRENDS AFFECTING THE WILDLANDS

There are three major changes shaping our nation wildlands. The first is urbanization, with an increase in wildland use as well as an increase in the number of people near wildlands. The second change is an accumulation of fuel loads, of both dead and live biomass, The third change is a shift in plant species composition towards climax.

Urbanization

Loss of homes in the chaparral of southern California first brought attention to the problem of urban encroachment into wildlands, but the problem has developed far beyond that. California's grasslands now have a natural succession from annual grass to intermingled ranchettes to subdivisions of thousands of homes. Similar succession is taking place in the woodlands of California's interior valley as well.

Development is being concentrated on grasslands and woodlands because these vegetation types are largely in private ownership and are next to historic population centers (which are usually situated near rivers). Additionally, grasslands and woodlands occur normally on flat locations, where it is easy (i.e. inexpensive) to build. Lastly, the profit motive is a driving force; certainly present economics dictate that more money can be made on homes than cows. Sadly, I see urbanization as the climax or ultimate steady state for these vegetation types in California, and by the year 2000 they therefore will no longer be considered wildlands.

The rest of this paper will therefore focus on the state of the forests in the year 2000, where the next wave of urbanization--nationwide--will take place. Bolsinger (1980) reported in 1977 alone that 220,000 acres of private timberland were being developed for non-forest use in California. This rate of development is probably being duplicated in every other forested state.

Removal of Wildlands From Production

The establishment of more homes around forests results in land being taken out of production for traditional commodities such as timber or grazing. The productivity of croplands and wildlands has been reduced nationwide more by development (via land use change) than by soil erosion.

Besides the loss of forest productivity due to direct land use conversion, there is a broader, more widespread loss of production around communities due to political forces. For example, the new inhabitants of the land previously classified as wildlands tend not to allow grazing or timber harvesting around their community. The prevailing sentiment is to have vegetation in their community surroundings remain the same, to let the little trees grow--of whatever kind, shape or vigor.

Increase of Values at Risk

Obviously urbanization greatly increases the values at risk. While the value of commercial timber is not negligible, the situation of a custom home on a half-acre clearing does significantly increase the values that need to be protected. As suburban encroachment into the forest continues, values at risk dramatically rise.

Limitation of Management Options

At the same time the new neighbors prohibit many uses of the forest, they also limit options for management, especially fuel management. The same two factors play here as in the issue of lost commodity production. The more direct cause of this limitation is the pattern of development, or the placement of homes. The situation of Stone Canyon, Los Angeles County, exemplifies the difficulties faced. Here homes are located on the ridge with their drinking water supply located below. The fuel in between is that which largely contributed to the "blow-up" in the 1961 Bel Air Fire. An innovative and ambitious program was required to treat the area. Elsewhere homes are routinely placed at the top of steep ridges and at ends of chimneys which greatly complicates the use of prescribed fire and heavy machinery. The distribution of these developments increases management cost, and limits how land management agencies can treat the wildlands.

Political pressure is the second, more indirect cause of limitations of options. For example, the same communities that simply would not allow prescribed burning during the 1960's may now advocate the use of fire, but disallow the use of herbicides. The new inhabitants will be more citified so the inconveniences posed by management activities will be increasingly unacceptable--whether it is ash in swimming pools or traffic from logging trucks. The allowances change with time and present a constant challenge.

Increase in Number of Ignitions

While the number of acres burned has been stable in California since 1964, the number of fires has almost tripled to approximately 11,500 (Bolsinger 1980). One constant is the weather, which will still consist of dry hot summers in the West. regardless of the vegetation and fuels. As usage intensifies, fire occurrence can be expected to increase further since the number of people have risen, and most fires are human caused. Eighty percent of all fires in California are started by roads so as we improve access, we spread the distribution of fires.

Most fire history studies find fire frequency declines with the onset of suppression. However, on the El Dorado National Forest off Highway 50 in California, a study discovered an increase in the number of fires after 1930 which were caused largely by campers and recreational use (Rice 1983). The impact of Highway 50 is very extensive now, as was the pony express and settling trails before. Road routes change, and settling trails consisted of a network of routes rather than narrow bands of travel. Both factors indicate fire impacted a much broader area than a roadside ribbon of land. The number of ignitions will increase where roads are established--often into areas of timber harvesting. Entire drainages are affected with new roads, because roadside fires in the valley floor commonly run to the top of the ridges.

Thus the trend of increasing urban encroachment into wildlands removes acres from production, restricts options for fuel management, increases values at risk, and increases the number of ignitions.

Fuel Accumulation

The second major trend in the wildlands is that the fuels are accumulating. This has been documented numerous times. For this discussion, accumulated fuels include standing live fuels in the biomass. So when a forest is thickly stocked or choked with underbrush, this too is a build up of fuels. Many dense forests appear productive, yet the space is taken with trees that are dead and dying because of suppression.

Heady and Zinke (1978) noted in Yosemite "forest stands have thickened with the continuous establishment of trees over the last 100 years." The current large amount of prescribed burning in this park has started to reverse this trend, but staff there admit even this aggressive program is just nibbling away at the backlog.

Gruell (1980) documented the fuel accumulation in the Bridger-Teton National Forest which was most apparent on productive sites where fire return intervals are short. He pointed out the importance of higher tree density where, in whitebark pines, fire behavior was a function of tree density. Where stocking was poor fire spread was not continuous, so it created an uneven-aged stand. In closed stands, fire behavior was much more intense, leaving an even-aged stand.

Shift in Species Composition Towards Climax

The third trend affecting wildlands is the shift in plant species composition to a more advanced successional stage.

Forests of the Sierras in the 1800's included large areas of "open and park-like" pine stands with little undergrowth. In contrast, the forest surrounding the Stanford Sierra Conference Center, where the Symposium was held, consisted of a white fir/incense cedar understory with a pine overstory. This is typical of the stand structure and species composition in the "new" California.

The "new" forest of California and throughout the West can be represented by the results of a stand age analysis done on the El Dorado National Forest (Rice 1983). Even though the old overstory consisted of ponderosa pine, no significant amount of pine existed as regeneration in the understory. The most apparent shift in vegetation was a shift in the proportion of canopy cover for each species. There were no new species on the site, and no species dropped out entirely, but the proportion of each species had shifted dramatically. Relative to other forests of the West, the area was a productive site. Additionally, the area was somewhat moist for a typical pine site. Because of these two conditions, succession proceeded more rapidly than on dry, or nonproductive sites. Species change may be happening more rapidly and before other areas in the West.

Nonetheless, a change in the composition of the forest has been observed widespread. Heady and Zinke (1978) predicted that if no catastrophe or management impact occurs, the previous black oak/ponderosa pine forests of Yosemite will be increasingly dominated by incense-cedar, white fir, Douglas-fir, and scrub oak. Gruell (1980) noted a subalpine fir understory in lodgepole pine and Douglas-fir forests. Spruce fir forests are also in a stage of late succession. He pointed out that the douglas fir forests are 100-125 years old, created by tremendous fires when the stands were in advanced succession. He linked the successional advances which were widely observed to a reduced fire frequency.

The stand age structure of a typical forest stand has shifted toward younger trees. This is obviously a product of the conversion of forests from old-growth to regulated stands. But additionally, the forest has become more densely stocked, largely of more shade tolerant trees, and with species less tolerant of fire. These trees can be expected to gain dominance by the year 2000.

Throughout history the seral species have been preferred timber. In Maine, white pine was logged to provide masts to outfit the King's navy. The hardwoods that replaced the pine are not now harvested with the same vigor. In the west ponderosa and sugar pine were logged in the 1800's while the more shade-tolerant species were left. So the shift to a greater proportion of climax species will tend to reduce the value of the timber output. Bolsinger (1980) stated that the mix of species harvested has changed because of both species availability as well as the market. Ponderosa pine and sugar pine comprised 70 percent of the wood used in California in 1869, 50 percent in 1946, and 23 percent in 1980. An increase in the cut of firs can be expected because of the large inventory of firs (now 28 percent of softwood volume in California).

Human impact has hastened this shift in species composition. During the 1800's harvesting reduced or eliminated the seed source of seral pines, which produced the first shift in species. This is an odd situation where logging caused a shift in species composition towards climax. Harvesting--like fire--in a gross way, can set the successional stage back a notch. But now, all forms of disturbance (other than grading and paving) are prohibited around communities, so the shift is more insidious, certain, and lasting.

As an indicator of change in the proportion of each tree species, the 1945 vegetation map by Wieslander explained the mixed-conifer classification as a pine - Douglas-fir - fir mix, while in the 1980 CALVEG map (Matyas and Parker 1980). the emphasis shifted with the mixed conifer classification described as a fir-pine mix.

This confronts the forester with a dilemma: One of the tenets of modern silviculture has been that the plant material most inherently adapted to a site is that found growing on the site. But it may not be so now. The present forests of the West require the forester to be part sleuth and part historian to determine what should be growing on any site. Yet even this may not be enough to change or divert the trend but only to chronicle it more precisely.

CONCERNS OF FIRE MANAGERS

The implications of the three trends are several. The foremost concern pertains to the increased number of ignitions in an increasingly vulnerable environment. Homes and lives are likely to be lost at an advanced rate from what we are used to seeing today. More and more forests may be lost as well. Fuel treatment takes place around areas of harvest, but initial logging roads open the forest to access and increased numbers of ignitions follow better access. The stands leading to and surrounding the harvest site may be hazardous, susceptible, and accessible. A long recognized impact of harvesting is the conversion of the local fire climate to one of greater windspeeds, and higher amounts of solar radiation which warms and dries fuels. These modifications in wind, air structure, and fuel moisture may result in greater changes in behavior than the temporary addition of more fuel in the form of slash (Countryman 1955).

Fire in young trees usually results in a total loss because they are not salvageable. As the large, old growth trees are removed and more of the forest is occupied by small trees. the relative effect of fire on yields will be more severe, and less of the fire-killed volume will be salvageable (Bolsinger 1980).

The serious implications with the shift in species relate to the ecological adaptations of the species to compete successfully. Pine and other seral species have manifested adaptations (litter fall, thick bark) that allow them to compete successfully in a fire regime of frequent occurrence. Firs and other climax species do not have these adaptations and so are less fire resistant.

Because of the increased stocking of the forest and multi-layer canopy, the distribution of fuels is more continuous, vertically and horizontally, than in the past.

Since fire occurrence can be expected to rise in the future, existing trees can be expected to be exposed to at least one fire during their life cycle. Fir and similar species of advanced successional stage can he expected to have a large mortality because of their lesser fire resistance and the conditions they produce to promote crown fires. The probability that stands of fir (or climax species) growing in places where pines (or seral species) have historically grown will reach maturity and eventually be available for timber is significantly less than it would be for pines were they maintained on the site.

The cards are stacked against the new vegetation reaching maturity, because of the increased number of ignitions and vulnerability. More fires will occur, each one with an increased probability that it will damage more trees and inflict greater damage to each.

Where fire is kept out, disturbance by insects or fungi is inevitable. As an example, Williams and others (1980) showed that outbreaks of Douglas-fir tussock moth largely occurred on pine sites now occupied by Douglas-fir. Douglas-fir growing on fir sites were not attacked.

The implications of increased amounts of dead material caused by acid rain has yet to be widely recognized. Acid rain will profoundly alter the fuel characteristics by increasing the dead-to-live ratio of forests to make them more flammable. As thousands of acres become affected, larger, and higher intensity fires are likely to result.

In Canada, some have advanced the idea of calculating the fire loss into long run timber yield assessments (Reed and Errico 1985, Martell 1980, Van Wagner 1983). What's interesting is that for fire sensitive species, even modest rates of fire can result in large reductions in long run yields, and shorter rotations.

Thus total resource damage will be greater with the new fire regime from the changed fuel complex. Not only are fires destroying homes and forests, but insects and acid rain will also damage forests in the future.

VISION: CLIMAX OR ANTI-CLIMAX?

In the best of possible worlds, the following five preferred scenarios would be the future:

1. Since fires cannot be entirely excluded in areas of high access and risk, the wildlands surrounding the border would be of low-fuel volume, fire-resistant species. This would be done by harvesting and intense fuel management in some places. Fuels would be treated on a frequency proportional to the fire return interval.

2. Forest practices would increase the proportion of seral species and reduce the amount of fuels in the wildlands. Pines would be planted after harvesting where they have historically grown. Both the composition of species and stocking of stands would be restored via firewood cutting, thinning, and other silvicultual [sic] treatments.

3. Fire loss--including that of timber producing stands and improved developments--would be minimized.

4. The public would be aware of forest dynamics and supportive of management activities. The public would trust recommendations of land managers.

5. Budgets would be adequate to accomplish mandated responsibilities and tailored to fit a project. Overall budgets won't increase, but money will be allocated for priority projects. Funding for management treatments would receive priority consistent with the increased values at risk Pre-emergency treatments will be as well supported as emergency measures.

How will we accomplish these visions, or turn the probable future--one of doom and gloom--into the rosy preferred future described above?

Much of the rosy future scenario depends on management treatments, most of which require funding. One exception may be the selection of species to plant, where most foresters are already choosing the most appropriate type. Another exception would be the regulation of firewood cutting to reduce stocking levels and fuel loads. All other treatments such as hazard reduction or thinning necessitates funding which, in turn, requires political support.

Homeowners are most likely to be the power base for action. They will empower officials to manage the land well. It is therefore incumbent on land managers to express the message that the profession is caring for the land and serving the public. If resource managers convince the public that they are skilled and have good judgement, this major powerbase will allow them to conduct the management activities needed.

Minimizing costs is not the main concern. Homeowners in California are making that a clear message. In the urban interface of the Berkeley/Oakland hills, officials are getting the message that homeowners would prefer to have lands managed with hand labor and goats, even after seeing that these treatments are sometimes 10 times more expensive than alternatives. The power of homeowners is also illustrated in the small City of Hercules where staff are trying to set up a tax assessment district, which would generate over $50,000 per year solely to reduce the fire hazard in the city's 300 acres of wildlands. This effort is because a small, vocal group of homeowners demanded that fires that burned their homes had to stop. In a surprising quote from Ecclesiastes. "A feast is made for laughter, wine makes merry, but money answers all things."

Although most people can be convinced of the necessity for management, there will be a hard-core group of those who wish to do nothing and spend nothing even in the face of impending disaster. With more clusters of small developments, this group will have in increasing impact.

Within the spectrum of management treatments, a shift toward presuppression activities should take place. This is especially important around communities. Pyne (In press) contrasted the United States' and Australia's fire protection strategies. Our protection strategy in the United States is based on the belief that any fire can be suppressed if hit hard enough when small enough. In Australia, on the other hand, protection strategy is based on the idea that the intensity of any fire (and thus damage) can be reduced if fuels are reduced. Hopefully we can reach a balance in the next millenium. The shift from the 10-A.M. policy (control of all fires before 10-A.M. of the following day) to the "three C's" (contain, confine, control) is a signal of this advance.

Four points serve as a summary. Our forests are changing in a way that sets the stage for more stand replacing fires through a shift in species and fuel characteristics. The forests are themselves more vulnerable to any fire and thus more difficult to manage. Increased fuel management will be a key activity to reduce resource damages. The homeowners in the local community will limit our options, or empower us to do our job well. Which direction will be taken depends on whether land managers take concerted action to educate and inform the public of the profession's integrity and skill.

REFERENCES

Bolsinger, Charles. 1980. California forests trends, problems and opportunities. Res. Bulletin PNW-89. Portland, OR: Pacific Northwest Forest and Range Experiment Station, Forest Service. U.S. Department of Agriculture; 138 p.

Countryman, Clive. 1955. Old-growth conversion also converts fire climate. In: Proceedings of the Society of American Foresters Meeting: 158-160.

Gruell, George E. 1980. Fire's influence on wildlife habitat on the Bridger-Teton National Forest. Wyoming. Volume 2--Changes and causes, management implications. Res. Paper INT-235. Ogden. UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 207 p.

Heady, Harold F.; Zinke, Paul J. 1978. Vegetational changes in Yosemite Valley. National Park Service Occasional Paper No 5. National Park Service, U.S. Department of the Interior; 25 p.

Jensen, Herbert A. 1947. A system for classifying vegetation in California. California Fish and Game 33(4): 199-266.

Martell. D.L. 1980. The optimal rotation of a flammable forest stand. Canadian Journal of Forest Research 10:30-34.

Matyas, Wendy; Parker. Ike. 1980. CALVEG: Mosaic of existing vegetation of California. San Francisco, CA: Regional Ecology Group, Forest Service. U.S. Department of Agriculture; 27 p.

Pyne, Stephen J. The fire next time: old fire problems and new problem fires. In: Proceedings, Ninth Conference on Fire and Forest Meteorology; 1987 April 21-24; San Diego, CA. American Meteorological Society; [In press].

Reed, W.J.; Errico. D. 1985. Assessing the long-run yield of a forest stand subject to the risk of fire. Canadian Journal of Forest Research 15:680-687.

Rice, Carol L. 1983. A fire history of the Ice House Compartment. Unpublished report to the El Dorado National Forest supplied by author.

Van Wagner, C.E. 1983. Simulating the effect of forest fire on long-term annual timber supply. Canadian Journal of Forest Research 13:451-457.

Wieslander. A. E.; H.A. Jensen. 1945. Vegetation types of California. Berkeley. CA. California Forest and Range Experiment Station. Forest Service, U.S. Department of Agriculture; map.

Williams, Jerry T.; Martin, Robert E.; Pickford, Stewart G. 1980. Silvicultural and fire management implications from a timber type evaluation of Tussock moth outbreak areas. In: Proceedings Sixth Conference on Fire and Forest Meteorology; 1980 April 22-24; Seattle, WA. Society of American Foresters; 191-196.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Visual Impacts of Prescribed Burning on Mixed Conifer and Giant Sequoia Forests[1]

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Abstract: Prescribed burning programs have evolved with little concern for the visual impact of burning and the potential prescribed burning can have in managing the forest scene. Recent criticisms by the public of the prescribed burning program at Sequoia National Park resulted in an outside review of the National Park fire management programs in Sequoia, Kings Canyon, and Yosemite National Parks. This paper evaluates the visual impacts of burning and of not burning in the giant sequoia-mixed conifer forest type. Alternatives to current techniques are suggested which will reduce the negative visual impacts and incorporate scene management as a part of the prescribed burning program. The need for a new awareness of the visual impacts of prescribed burning is discussed.

Dateline Three Rivers. California, November 7, 1985:

> "The sun rising over the Great Western Divide was stained orange this morning by clouds of smoke towering a thousand feet above Giant Forest. The irreplaceable Big Trees of the Sierra were being blackened and eaten into not by lightning fires, but by blazes set and allowed to run.

"Now, in the burns under way the litter of down trees and branches that naturally accumulate against the hillside giants has not been cleared in a prudent manner prior to ignition. The result was predictable: raging flames at the butts, deepening and widening the ancient fire scars whichof these giants exhibit. Further, the cinnamon-colored bark was scorched black upwards of forty feet....

"The merits of fire to 'restore the eco-system,' are not debated here. Rather, we point to the myopia which cannot perceive that pitchy materials accumulated over decades when set alight will create havoic [sic].... The observable fact, that injury to the base of the sequoias causes the top to 'die back,' is beyond debate. What benefit have we then arrived at with our imprudent burning if we 'restore the eco-system,' but lose the giants of the forest?

"With the rationale of protecting the life of the forest community the very specimens we have been entrusted to shield from destruction may be severely weakened.

"Take what actions you feel most effective to question any mismanagement of our heritage. Alert newspapers and TV stations. Create caravans of inspection. Take pictures, make tapes. Contact Senators, Congresspersons, and Director. National Parks Service. William Penn Nott, Jr." (Challacombe 1985).

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So begins the story of recent criticism surrounding the burning program at Sequoia and Kings Canyon National Parks. Sparked by the zealotry of a single critic, Eric Barnes, media attention focused on previously undoubted management practices. Headlines like "Naturalists fear park service 'charcoal broiling' rare trees," "Controlled fires under sequoias spark concerns," "To burn or not at Sequoia," "Don't take any chances with sequoias," and "Growing criticism over controlled sequoia burns" demonstrated the lurking power of public review, particularly where popular scenery is at stake.

The National Park Service responded to this heat by appointing a panel to review its fire program and by postponing scheduled burns in Sequoia National Park.

By the year 2000, public outcry over perceived defilement of scenic amenity in popular parklands might preclude such a studied response. In the probable future, the public will make increasing use of highly scenic and accessible areas as baby-boomers age into retirement. Public supervision of prescribed fire and other management practices will steadily increase. Popularly perceived and familiar scenic amenities will be increasingly guarded as national resources.

Does this mean there is no future for prescribed burning in sensitive public recreation areas? What visual concerns must be addressed by alternate burn programs to effectively reduce negatively perceived impacts? In the year 2000. will prescribed fire in scenic areas be severely limited or eliminated altogether, or will it be designed to produce acceptable visual impacts while actually improving scenic recreation potential?

BACKGROUND OF THE PROBLEM

The removal of Native Americans and the establishment of fire prevention and control programs by the first managers of National Parks in California resulted in a significant lengthening of the intervals between fires. This change in the length of the fire free interval has been documented by Wagener (1951), McBride and Laven (1976), Kilgore and Taylor (1979), and Warner (1980). Fire-free intevals [sic], which averaged around 10 years during the Native American period, have been extended to around 50 years in many parts of the mixed conifer forest type in California. The effects of the lengthening of the fire free interval has been to (1) increase fuel loading (Biswell and others 1966), and (2) change the appearance of the forest (Cotton and Biswell 1973).

Two important visual changes have resulted from the extension of the fire free interval. The first change has been a reduction in visual penetration due to the establishment of white fire (Abies concolor) and incense cedar (Calocedrus decurrens). Kilgore (1972) used a comparison of photographs taken in the 19th century in giant sequoia (Sequoiadendron giganteum) groves with photographs taken in the 1970's to demonstrate the establishment of an understory of white fir. It is evident from these photographs that visual penetration has been reduced. Visual penetration has been reduced. Visual penetration into the forest understory is a factor that correlates with scenic preference in forested landscapes (Bacon and Twombly 1979. Kaplan 1979, Walter and others 1979). Reduction of visual penetration reduces the variety of the scene. In the case of the giant sequoia-mixed conifer forest, a reduction of visual penetration often prevents the viewer from seeing many giant sequoia trees from a single location.

The second important visual change resulting from the extension of the fire free period has been the change in the appearance of the base and lower trunks of the individual trees. Trees charred by fire have sloughed charred bark in the long intervals between fires. Forest visitors in the second half of the 20th century have seen few trees with any extensive areas of charred bark. The unblackened cinnamon bark we associate with the trunks of the giant sequoia may not have been as common to the Native Americans or the American pioneers who viewed these same trees over a century ago. An examination of photographs by Chorover (1986) of giant sequoia trees in Yosemite and Sequoia National Parks taken prior to 1900 indicate that about 12 percent of the trees have basal bark char. A field reconnaissance of Calaveras Big Tree State Park by the authors revealed less than one percent of the giant sequoia trees have basal bark char, however, all. trees over 10 feet in diameter at breast height (d.b.h.) show some evidence of past fires. People have come to expect an uncharred trunk for a giant sequoia.

The initiation of prescribed burning programs in the giant sequoia-mixed conifer forests has the potential for both positive and negative visual impacts. Prescribed burning, when coupled with judicious removal of fire-killed understory trees, can restore visual penetration into the forest. Procedures developed by Harold Biswell (1986) at the University of California Department of Forestry and Resource Management's Whitaker's Forest and Glen Walford (1986) at Calaveras Big Trees State Park have restored visual penetration by eliminating areas of dense white fire regeneration. Prescribed burning can, however, have a negative impact on the visual quality of the forest. This negative impact results from the charring of bark and the presence of fire killed understory trees and shrubs. The experience at Sequoia National Park is evidence of the negative impact of prescribed burning. The sudden presence of numerous trees charred bark was probably the key factor leading to the citizens' protest against the prescribed burning program. Charred bark was also a factor in local objections to the burning program in the redwood (Sequoia sempervirens) forests of the Santa Cruz Mountains (Greelee 1985). In this latter instance Greelee burned on level ground when there was no breeze, which resulted in scorch up to 90 feet. Biswell (1986) burned on sloping ground in the same area and produced no significant scorch due to better disbursement of heat in the crowns, He noted that tree limbs greater than 6 inches in diameter were undamaged and sprouted after burning, greatly reducing adverse visual impacts from prescribed fire.

Taylor and Daniel (1985) have demonstrated that the change in appearance of trees and forest stands following prescribed burning results in decreased scenic quality ratings and reduced recreational acceptability. Their study showed a decreased preference and lower scenic rating among forest visitors, even after receiving information on the beneficial effects of fire on the forest. Hammett (1979) documented a high correlation between familiarity and visual preference. Unfamiliarity with charred trees and fire-killed regeneration on the part of the 20th century public probably has contributed to dissatisfaction with the results of prescribed burning. Martin (1986) has suggested that if we could take a survey of Native Americans who lived in the giant sequoia-mixed conifer forest prior to 1865, we would find a high degree of acceptance of trees with charred bark. However, we are not dealing with a public composed of pre-20th century Native Americans. Our public has not had a familiarity with bark charred trees in our National Parks. Whether we can or should educate the public to accept charred trees is a difficult question to answer. Zajonc (1980) has offered persuasive evidence that our judgements about preferences may be fairly independent of the cognitive process. He suggests that feelings often dominate the cognitive process when it comes to our preferences.

> "Even the most convincing arguments on the merits of spinach won't reduce a child's aversion to this vegetable" (Zajonc 1980 p. 172).

SOLVING THE PROBLEM

Alternatives to reduce negative impacts while creating positive impacts from prescribed burning are needed. Pre-fire site preparation can reduce bark char on specimen trees, and post-fire felling, stacking, and burning of fire-killed understory trees and other charred materials can significantly reduce negatively perceived visual impacts of prescribed burning.

Early work by Biswell and others (1968) at Whitaker's Forest, and Biswell (1986) and Walford (1986) at Calaveras Big Trees State Park demonstrates what prescribed burning can be used in the giant sequoia-mixed conifer forest in ways that minimize the negative visual impacts often associated with it. These procedures involve the removal of litter and heavy fuels from the base of trees before burning.

At Calaveras, litter was raked back 2 or 3 feet from the base of each large giant sequoia, and heavy fuels were thrown or moved to the side or above each tree to a distance of 10 to 15 feet. Following the fires, dead trees within the stands were felled, as were some living intermediate sized trees within 6 feet of giant sequoias.

At Whitaker's Forest, understory white fire and incense cedar under 11 feet tall were also cut, piled, and burned prior to the broadcast burning of the forest floor. At Calaveras Big Trees State Park's South Grove, local areas of fire-killed white fire and incense cedar and other charred materials were cleared after the prescribed burns. Biswell noted that in neither case were understory trees felled and not preburned prior to broadcast burning. He feared that the additional fuels on the ground would make too much fire and produce visually unacceptable impacts.

These site-preparation and post-fire activities are labor intensive. In the late 1960's, Biswell spent $243 per acre on preparation and post fire hand work, using inexpensive convict labor. He estimates that the same work today might cost upwards of $1000. Expenditures amounting to $550 per acre were required at Calaveras in 1981. This seemingly expensive site preparation work practically eliminated the charring of the tree bark and the residual charred visual artifacts of the prescribed burning.

The removal of understory white fire and incense cedar additionally restored visual penetration into the forest, recreating the essential character of the open, park-like forest. In doing this understory vista clearing, Biswell (1986) and Walford (1986) were guided by the late landscape architecture professor, Leland Vaughn from U.C. Berkeley, who identified the importance of retaining clusters of understory regeneration to frame vistas and create a sense of sequencing in views as seen from trails. In broadcast burning, clusters of young trees are naturally retained in openings where fuels are insufficient to consume them. Another potentially positive visual impact of prescribed fire can be the fresh exposure of old firescars, scenic curiosities of great interest to the public. At Whitaker's Forest on an 80 acre plot, Biswell studied the firescars on 50 sequoias between 8 and 16 feet d.b.h. No two were alike. Scorch and char, being natural, should not be eliminated as visual elements. They should, however, not be greatly increased in extent as a result of prescribed fires, particularly restoration fires.

CONCLUSIONS

The recent history of prescribed burning in the sequoia-mixed conifer forest type provides a basis for some conclusions about the probable future involvement of visual criteria in managed fires. These conclusions are based in part on the findings of the Christensen Panel which investigated the prescribed burning program in Sequoia, Kings Canyon and Yosemite National Parks and the response of the National Park Service to the report. In short, the panel found a need to recognize the negative visual impact of charred bark and the positive role landscape architects could play in planning prescribed burns.

The major recommendations of the panel's report (Christensen and others 1987) are as follows:

1. Prescribed burns planned for areas managed as natural ecosystems should be classed as:
    a. Restoration fires--fires to manipulate fuel conditions judged to be "unnatural."
    b. Simulated natural fires--fires intended to maintain the natural fire regime.
2. Showcase areas should be expanded in areas where scene management is of primary concern.
3. Reevaluate the policy of using natural fire return intervals based only on lightning caused fire. The National Park Service should consider the fire return interval during the Native American period in the adoption of a fire return interval to be used in prescribed fire management.
4. Landscape architects should be consulted in the development of burn plans.
Aesthetic concerns should be addressed in selecting from among ecologically acceptable alternatives.
5. A formal external review program should be initiated to review fire management plans.

Specific suggestions for modification of existing burn plans were as follows:

1. Judicious preburn cutting of live trees to minimize bark char and crown scorch.
2. Removal of heavy fuels from the base of all large trees in restoration areas.
3. Use of single-burning front, rather than multiple-spot ignition, in simulated natural fires.
4. Manipulation of debris following burning if prescribed burning has exacerbrated [sic] heavy dead fuel conditions. Additional local burning is advised to achieve fuel reduction objectives.

The recommendatins [sic] represent the kinds of changes in existing prescribed burning programs that are designed to reduce fuel loading or to reintroduce fire into National Parks, which we think are necessary to minimize the negative visual impacts of prescribed burning. We believe it will be imperative that resource agencies wanting to use prescribed burning as a management technique in the 21st century recognize the potential negative visual impacts. Public concern over the impact of prescribed burning on air quality has led to the intervention of air pollution control officials in the selection of climatic conditions when burning will be allowed. We believe that similar intervention will occur unless foresters and park managers address the negative visual impacts that are occurring as a result of current prescribed burning techniques.

The National Park Service has endorsed the recommendations of the Panel. The fire management staff, augmented by a landscape architect, is revising the burn plan for the Keyhole and Tharps burns scheduled for 1987. The recommendations to reduce bark char, scorch height, and to take advantage of scene-management opportunities on restoration fires as proposed in the Panel Report have been adopted. An additional impact of the report has been the base funding of the Sequoias prescribed burning program at $80,000. The response of the National Park Service is an example of the response other agencies will need to adopt in dealing with the potential negative visual impacts of prescribed burning in the next century.

Back to the future, our preferred future, by the year 2000 we could have a management ethic in which informed scenic and recreational considerations influence wildland fires as part of a multidisciplinary planning program. This might include interpretation programs that aim to remake the public's preferences, presenting dazzling images of carbon etching to use an unloaded term for char. More potentially influential, however, will be changes to prescribed fire programs resulting from the involvement of individuals professionally trained and competent to identify and communicate alternatives based on intuitive judgements. Such people, landscape architects and planners who specialize in guiding work that heightens environmental sensory perceptions and in utilizing behavioral studies related to recreational areas could lead to strengthening the visitor's visual image of unique scenic elements resulting from prescription fire. In addition to greater visual penetration, there is the potential actually to improve scenic opportunities through experimental sequencing such as Biswell (1986) and Walford (1986) employed at Calaveras, setting the visitor up for a thrill.

In conclusion, we paraphrase that enduring Talleyrand (Bartlett 1980) quotation that "War is much too serious a matter to be entrusted to the military," by proposing that scenic integrity in the giant sequoia-mixed conifer forest is too serious a matter to be left up to the resource scientists. Rather, design consciousness, developed through multidisciplinary involvement and utilizing ecologically acceptable alternatives within the scope of vibrant process management, could be the key to retaining public support for prescribed burning.

REFERENCES

Bacon, W.R.; Twombly, A.D. 1979 Visual management system and timber management application. In: Elsner, G.H.; Smardon. R.C., eds. Proceedings of Our National Landscape: A conference on applied techniques for analysis and management of the visual resource: 1979 April 23-25; Incline Village, NV. Gen. Tech. Rep. PSW-35, Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 539-546.

Bartlett, J. 1980. Familiar Quotations. Boston, MA: Little, Brown and Company; 401 p.

Biswell, H.H.; Gibbens, R.P.; Buchanan, H. 1966. Litter production by big trees and associated species. Calif. Agric. 20:5-7.

Biswell, H.H.; Gibbens, R.P.; Buchanan, H. 1968. Fuel conditions and fire hazard reduction costs in a Giant Sequoia Forest. National Parks Magazine, August, 1968.

Biswell, H.H. 1986. Prescribed burning in Giant Sequoia. Personal communication.

Challacombe, R. 1985. Sequoias in Flames. Xeroxed leaflet. 1 p.

Chorover. 1986. Analysis of bark char and fire scar on old photography. Personal conversation.

Christensen, R.; and others. 1987. Review of Fire Management Program for Sequoia-Mixed Conifer Forests of Yosemite, Sequoia and Kings Canyon National Parks. Washington DC: National Park Service. U.S. Department of the Interior; 51 p.

Cotton, L.; Biswell, H. 1973. Forestscape and fire restoration at Whitaker's Forest. National Parks and Conservation 47(2): 10-15.

Greenlee, J. 1985. Personal Communication.

Hammett, W.E. 1979. Measuring familiarity for natural environments through visual images. In: Elsner. G.H. and Smardon. R.C. (Technical Coordinators). Proceedings of our National Landscape: A conference on applied techniques for analysis and measurement of the visual resources; 1979 April 23-25; Incline Village NV. Gen. Tech. Rep. PSW-35, Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 217-226.

Kaplan, S. 1979. Perception and landscape: conceptions and misconceptions.

In: Elsner, G.H.; Smardon, R.C., eds. Proceedings of Our National Landscape: A conference on applied techniques for analysis and management of the visual resource: 1979 April 23-25; Incline Village, NV. Gen. Tech. Rep. PSW-35, Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 241-248.

Kilgore, B.M. 1972. Fire's role in the sequoia forest. Naturalist 23(l):26-37.

Kilgore, B.M; Taylor. D. 1979. Fire history of a sequoia-mixed coniferforest. Ecology 60: 129-142.

Martin. R. 1986. Personal Communication.

McBride, J.R.; Laven. R.D. 1976. Scars as indicators of fire frequency in the San Bernardino Mountains, California. Journal of Forestry 74:439-442.

Taylor, J.G; Daniel, T.C. 1985. Perceived scenic and recreational quality of forest burn areas. In: Proceedings-Symposium and Workshop on Wilderness Fire; 1983 November 15-18; Missoula, MT. Gen. Tech. Rep. INT-82. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 398-406.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Local Planning Considerations for the Wildland-Structural Intermix in the Year 2000[1]

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Abstract: California's foothill counties are the scene of rapid development. All types of construction in former wildlands is creating an intermix of wildland-structures-wildland that is different from the traditional "urban-wildland interface." The fire and structural environment for seven counties is described. Fire statistics are compared with growth patterns from 1970 to 1985. Potentials for the year 2000 are suggested. California planning law is overviewed in relation to development. Local governments and fire services have underutilized existing authorities in describing and mitigating fire impacts in the intermix. Productive ways of improving mitigation requirements are suggested. A stronger planning-related partnership between fire services and local government is called for. Recommendations are made in the areas of legislative improvements, applied research, and strategic fire pre-planning. The study is presented from the perspective of a retired fire management specialist who is now a County Planning Commissioner.

The presence of structures in wildland areas of California has been a continuing fire problem for over 60 years. As population and development increase, so do the cost and loss impacts of wildland-structural fire. Whether structure fire spreads to wildlands, or wildland fire ignites structures, the complexities of wildland fire management are drastically increased by all forms of development. The problem has mushroomed in seven California "foothill" or "Mother Lode" counties used as a study area. Fifteen years (1970 to 1985) of history confirm that fire trends follow population increases. Those trends indicate that a significant impact has already occurred. Growth predictions to the year 2000 indicate that greater impacts are ahead.

The study area represents a change in character of the wildland-structural relationship from "interface" to "intermix." Former boundary definition between structural encroachment and wildlands has essentially been lost; structures are now present on a random or matrix pattern throughout large areas. The intermix adds another dimension of difficulty to fire suppression, increases costs and losses, and presents additional threat to public safety. Neither local government nor fire services have adequately recognized this problem. Unacceptable adverse impacts will undoubtedly occur in the future unless changes are made in both fire management and local planning procedures.

THE STUDY AREA

Seven counties in the east-central portion of California were chosen as the study area: Nevada. Placer, El Dorado, Amador, Calaveras, Tuolumne, and Mariposa. These are usually referred to as the "foothill" or "Mother Lode" counties. Each contains substantial areas of National Forest land, and Yosemite National Park is located in parts of Tuolumne and Mariposas Counties. Federal lands were excluded from the

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study. Incorporated areas and the western portions of Placer and El Dorado Counties, which are essentially urban in character, were also excluded. About 3 million acres, or 3 percent of California's total land area are in the study area. However, if Federal lands, established urban areas, and all "otherwise dedicated" lands in the state are considered, the study area actually represents about 10 percent of the land available for development in the next 13 years.

Fire Environment

Elevations rise from about 1000 feet in the western or "valley" areas, up to a range of 4000 to 6000 feet where unincorporated areas abut National Forests on the east. Major river drainages traverse each county. Their major and tributary drainages sharply divide terrain in the eastern portions of the area, and flow out to gently rolling hills at the lower western elevations. Slopes are greater than 100 percent over more than half of the area, and slopes of 35 to 50 percent are common over the remainder.

Fuel types begin with annual grasses in the lower elevations and change to oak-woodland, soft chaparral, mixed brush and timber, and mixed-conifer as elevations increase. Fuel loading varies from about 2 tons per acre in grass to over 100 tons per acre in the timber zones. Normally, fire season begins in late April-early May and lasts until October. Daytime temperatures often exceed 100° F, relative humidity drops below 20 percent frequently, 1-hour fuel moisture (at 1400 hours) usually drop below 3 percent, and 10-hour fuel moistures of 4 and 5 percent are common. Local winds vary with topography and diurnal patters; "Red Flag Warnings" caused by strong gradients occur at least twice each fire season.

Population and Fire Trends

Past and present population figures for the study area were obtained from the California Department of Commerce (1985). Predicted populations were taken from the California Department of Finance (1984). Population estimates for the year 2000 are adjusted downward by 30 percent to reflect growing urbanization in the study area.

California Department of Forestry "Annual Statistical Reports" (1970-1985) were used to aggregate fire statistics for the seven counties. Predicted fire incidence is taken from the Department's 1985 draft "Fire Protection Plan."

Table 1 compares fire and population data for the "benchmark years" of 1970, 1985, and 2000.

There is strong correlation in the percentage increases between population, number of fires, and acres burned for the 1970-85 period. Population and fire predictions for the year 2000 indicate that the relationship will continue. No prediction for acres burned is available, but past data suggest that this total will also increase, perhaps by as much as 50 percent. Even if more fires are kept to smaller sizes in the future, a 47 percent increase in incidence will have an escalating effect on acres burned.

Damage figures are "actual year" totals, and are not corrected for inflation. The totals are a combination of natural resource and structural damages. The astronomical (5000 percent) increase between 1970 and 1985, combined with the predicted increase in number of fires is a

Table 1--Study Area Fire and Population Data for "Benchmark Years"

	1970	1985	(percent increase)	2000	(percent increase)
Population	151,000	298,000	(97)	450,000	(51)
Fires	860	1.635	(90)	2,500	(47)
Acres burned	5,600	10,900	(95)	N/A	N/A
Damages	$93,000	$5 Million	(5000)	N/A	N/A

strong indicator of future impact. Natural resource values will increase, and construction costs will follow the same trend. The Department of Forestry study supporting their Fire Protection Plan (1985) states that less than 1 percent of all fires cause about 75 percent of recorded damages. If that same ratio continues, the increase in number of fires and higher values will combine to bring expected damages up to about $10 million (1985 dollars) annually by the year 2000.

This information shows that a clearly "significant fire impact" has already occurred, and that future population increases will bring even more detrimental effects.

Impact of the Wildland-Structural Intermix

Sheer numbers of people adversely impact the fire situation. Where and how they locate complicates the issue and compounds the challenge of effective protection. Both the pattern and type of development influence the fire environment.

In the study area, the observed pattern of development began to take shape in the early 1960's. Widespread availability of land allowed people to purchase homesites anywhere they found them attractive. Planning and zoning procedures of the time made it easy to create parcels, permitted a wide variety of uses, and placed minimal restrictions on access and water-supply requirements. The limited infrastructure (particularly water and road systems) of local government essentially forced scattered development: It was easier to put these developments "on their own" to meet their needs because local government could not. Laissez-faire attitudes of local officials encouraged development with minimal constraints.

As the population increased through the 1970's, the numbers of service and commercial businesses also increased. These were also allowed to locate relatively freely, and although more health and safety measures generally were required, access and water supply standards remained low. The whole process accelerated in the 1980's. However, during the late 1970's and early 1980's, planning, zoning, and fire service procedures matured, and major developers began to improve subdivision design. The 15 years between 1970 and 1985 brought incremental improvement to development of all types.

The study area is now a conglomerate of private, commercial, and industrial development, of old and new, and of good and poor structures. A random, leap-frog pattern of structural types and uses exists. Government infrastructures are only slightly better than they were a decade ago: serious access and water supply problems are still present. All of this exists in a mountainous, heavily-vegetated environment, creating a heterogeneous mixture of wildland-structures-wildland. This wildland-structural intermix is different than the traditional "interface." The intermix is a greater challenge for fire managers because it requires different approaches to fire suppression and fire planning. The traditional interface. for example, implies some kind of boundary or defined perimeter that can be defended along some kind of front. And once the front is defended, the fire becomes clearly structural in character, or clearly wildland. This is not the case in the study area: while some interfaces do exist, they are not "true" or "final" because additional structures are located in close proximity. Structural threat can be dealt with at the interface but it is never eliminated in the intermix.

The wildland-structural intermix creates three impacts that are not totally recognized by local government, and may not be fully appreciated by fire services. First, it requires an increased fire management capability, that of managing both wildland and structural forces at the same time (another "mix"). Second, it materially increases costs: protection of life and property become primary objectives and all nearby structures must be guarded by additional forces, even though they may not be directly or immediately threatened. Finally, defense of structures inevitably results in greater natural resource losses. The priority of life and property defense overrides wildland protection, and acres are sacrificed to save homes.

In the study area, the intermix pattern is firmly established. It will not change in character by the year 2000, despite any local government efforts at "infilling" or consolidating development into more of an interface arrangement. The intermix problem will not be "solved" in any final sense, and the additional costs and losses will undoubtedly continue. However, if both fire services and local governments improve their combined approach to intermix fire planning. those impacts can be held to much more acceptable levels in the future.

FIRE NEEDS MORE EMPHASIS IN LAND USE PLANNING

The California Government Code establishes a hierarchy of planning law. At the top of the ranking is the requirement for local government General Plans (Section 65300). Several legal judgements declare that General Plans are the "Constitution for local development," indicating their primary position in the planning process. General Plans are required to have seven elements describing how the legal jurisdiction will manage planning and development for the general health and welfare of its citizens. A Safety Element is one of the mandated seven, and must describe local policies for the protection of the community from "fires, seismic, and geological hazards."

The Safety Elements for the seven counties in the study area were reviewed with specific attention to wildland fire and the wildland-structural intermix. A wide range of quality was found. Some plans displayed a good grasp of the wildland fire problem, but most were weak. None of the plans demonstrated an understanding of the intermix problem, and none had any preventative or mitigating policies oriented toward reduction of the intermix fire challenge.

A "profile of benign neglect" for the intermix developed around five characteristics common to all plans.

1. Relative Importance Given to Fire Versus Other Hazards

Although the study area is one of the more seismically-stable areas of California, the seismic component of all Safety Elements vastly outweighs the consideration of the annual impacts caused by wildland fire. Serious flooding occurs about every 15 to 20 years, but it too is better documented than the annual fire problem. Fire receives about 20 percent of the attention given to the other hazards. Earthquake and flooding descriptions are supported by considerable scientific data. With one notable positive exception, fire is not supported by anything more than cursory discussion. Fire issues that are mentioned in Safety Elements are strongly oriented toward the structural concerns that can be addressed through application of the Uniform Fire and Building Codes.

2. A "Case-by-Case" Perception of Development

All of the plans treat fire on a "single-project" basis. Individual development policies are cited throughout: "the project" and "the development" are terms used exclusively. Only two of the plans mention fuelbreak requirements. Otherwise, there is no narrative awareness that any project impacts (or may be impacted by) a larger fire environment.

3. Omission or Abuse of Fire Hazard Severity Classification

Only three of the counties include the Fire Hazard Severity Scale developed by the California Department of Forestry. One county politically and arbitrarily reduced all levels of hazard, eliminating the "Extreme" rating altogether, and probably violating the legal requirements of its Safety Element. The absence or abuse of fire hazard data places citizens in some rather dangerous situations, and further compounds the intermix dynamic.

4. The "Intermix Paradox"

To a large extent, the intermix pattern of development was entrenched before General Plans were mandated in 1971. The random characteristics that existed then (and have continued since) were essentially encouraged by local governments for a variety of reasons. In the early 1980's most of the study area plans were revised or reissued. The random developments had to be recognized as legal in the "new" plans, regardless of the fire safety of the structures involved. However, in what appears to be a well-intended but misguided approach, the current plans encourage further intermix. All plans contain policies to "maintain low density in high fire hazard areas" or "limit development to one dwelling unit per 20 acres (or 10 or 5 acres)."

The apparent logic behind these policies is to limit potential for structural conflagration in areas of limited fire defense capabilities. The end result, however, is to escalate the fire problem in the wildland-structural intermix.

5. General Plan "Diagrams

The law mandating General Plans does not require "maps," only "diagrams." This distinction was a conscious legislative act to provide local government a degree of freedom in "approximating" planning rather than forcing exact precision of parcel delineation, zoning. and land use classification. The distinction is valuable and efficient for general planning purposes, but it has drawbacks from the fire safety standpoint. For example, the study area plans all had some kind of actual maps (soil-vegetation surveys, fire jurisdiction boundaries, and others). These were used as reference data only, in support of the fire components of their plans. The actual "working documents" presented and used in final planning decisions were the diagrams.

The diagrams present a "flat earth" character: they are planimetric, color-coded in ways that obscure fire information, and most were on map bases of 1970's vintage. The average citizen, developer, planning commissioner, or elected official cannot grasp any realistic concept of the fire environment from these diagrams. Without that ability, final planning decisions tend to be less than adequate, if not detrimental, to fire protection interests.

LOCAL PLANNING CAN BE IMPROVED

The study found no evidence that these neglected or weak elements were the results of any conscious effort on the part of planners or governments. (The arbitrary modification of the Fire Hazard Severity Scale may be an exception.) Most planners were satisfied with the way their Safety Elements recognized local fire issues, and none perceived the weaknesses. Any feelings of dissatisfaction were focused on the need to refine existing policies rather than on improving recognition of the intermix problem in their Safety Elements.

Fire personnel also reported general satisfaction with current situations, especially as compared with the conditions that existed in the 1970's. Most concerns of the fire discipline focused on gaining political acceptance for strengthening specific requirements such as roofing materials, fire flows, and project access. All fire managers reported a strong awareness that they were approaching the limits of capabilities. Some spoke of reaching a "lower threshold of suppression effectiveness." However, this perception seemed to be based upon being overwhelmed by sheer increase in numbers rather than in basic inadequacy of the planning process.

Both fire and planning disciplines saw the basic problem as the need to do better with what they had, to improve the "here and now," and to become more effective in dealing with specific issues. The weaknesses that exist in the planning framework, or the fact that reduction or correction of those weaknesses could improve the total fire environment were not initially recognized.

However, there is strong reason to believe that much of the weakness could be corrected by providing legal and technical guidance to both fire managers and planners. For example, the preponderance of seismic data is in the Safety Elements because the California Division of Mines and Geology developed guidelines for planners. The flooding background data is in the plans because hydrologists designed ways for that data to be included, and the legislature directed its inclusion. In both cases, description and technical proof of general public hazards were provided to local governments. To date, fire services (at all government levels) apparently have concentrated their inputs case-by-case on issues. However, new effort to improve basic input to local General Plans can change that. A new planning framework can be developed that will provide local government with stronger guidelines for fire safety. California planning law already provides statutory direction, supported by court decisions, to make positive change.

General Plan Guidelines

California's Government Code. Section 65025, directs the Governor's Office of Planning and Research (OPR) to give priority to the development of land use policies "in areas which require special development regulations because of hazardous conditions" (OPR 1985. p.9). Section 65040.2 authorizes OPR to "revise General Plan guidelines" using professional recommendations (op cit p. 16). Section 65400 requires local governments to "develop effective guides ... for the preservation of ... natural resources---and the efficient expenditure of public funds" (op cit p.53). The wildland-structural intermix has been shown to be a "hazardous area", prone to annual wildfire and threatening to life, property, and natural resources. The significant predicted impacts present fire services and planners with the obligation to improve General Plan guidelines through these legal avenues.

Scientific Data

Section 15064 of the Administrative Code calls for public agencies to base environmental decisions "to the extent possible on scientific and factual data" (Tuolumne County 1983, p. 23). The amount of currently available, scientifically valid fire and fire behavior data far outweighs that now present in General Plans. Much of that data could be included (as with the seismic information) to support planning decisions. Fire behavior modeling could be applied on a macro-environmental basis to depict large-scale local conditions related to general planning, and on a micro-environmental (case-by-case) basis to suggest individual mitigation measures. Such applications would make it difficult for local governments to ignore or misuse the information.

Off-Site Improvements and Protection Networks

Sections 66410 and 66498.1 of the Government Code encourage local government to develop a broad and external perspective of individual projects. Protecting the health and safety of people in the "immediate community" and considering the "relationship to surrounding areas" is required (Curtin 1986. pgs. 63, 74) (OPR 1985, p.260). Section 65560 which authorizes open space zoning to protect public health and safety specifically allows their "linking" to connect "areas requiring special management because of hazards ... such as fire risks." Several legal decisions and an Attorney General's opinion in 1984 indicate that areas dedicated for public purposes (e.g. zoning for fuelbreak, fuel reduction, or other suppression activities) can require "proper improvement by the subdivider so that they not become a burden" on the general taxpayer (Curtin, p. 63). These points provide an opportunity to plan integrated fire protection networks and improvements in a cost-effective manner. Fire safety requirements can be extended beyond single project boundaries, and overcome the case-by-case limitations that are prevalent today.

Upgrading Visual Understanding

Foregoing examples have cited legal bases for improvement. With the exception of "Scientific Data" as noted above, no laws or legal judgments support use of more descriptive tools, such as computer-compatible aerial photography and mapping. However, use of such tools would improve understanding and communications concerning the intermix fire situation. Most environmental disciplines have used them as state-of-the-art for years. Acquisition and use of modern photography and mapping by local governments should be encouraged by fire services and planners. Better understanding of the fire environment and better fire planning decisions in the intermix should result.

Revising Input To General Plans

Planning law requires "internal consistency" in General Plans. In the case of intermix fire problems, that consistency begins with more thorough description of the conditions and impacts created by structural intrusion into wildlands. The fire component of Safety Elements needs expansion based upon the generations of knowledge and scientific data available to fire services. Revised input to general planning, and Safety Elements in particular, is required before significant change for the better can come about in the intermix. Local planning procedures flow from general planning. The impacts, conditions, and possible mitigating requirements are all described based on the overall "picture" developed in the "Constitution" or master document. Failure to adequately describe impacts and justify protection measures in the Safety Element probably preclude implementation of any opportunities for improvement. The fire input to General Plans must be increased in both quantity and quality before they can be improved significantly.

THE SUBDIVISION MAP ACT

The Subdivision Map Act was not originally planned to be a subject of this study. However, its presence and its consequences were pervasive, particularly to fire services. The Act has long standing in California law and the manner of its application has great bearing on development patterns (and fire challenges) over much of the study area. Essentially, the Act establishes different procedural requirements for land divisions of four or fewer parcels, and for those of five or more. The smaller divisions historically have been easier to create, and fewer planning or public safety conditions have been mandated for those parcels. The study area contains thousands of small (1 to 5 acres) parcels, which were once parts of much larger holdings. Those original holdings were "split" into four parcels, split again into yet smaller ones, and many times those were divided again. The process is termed "lot-splitting" and the parcels are called "four-by-fours".

The long history of lot-splitting and the absent or limited controls applied to them make structural developments on these parcels a serious fire suppression challenge. Access is poor and water systems, when present, are of pioneer design and capability. Most of the developments are located in topographic and fuels situations that preclude effective suppression during high fire danger. The presence of vulnerable structures in these areas represent a threat to themselves and to other developments in the vicinity. When such parcels are associated with major fire, either as ignition site or in the path of fire spread, they are most likely to be the point(s) where containment will be most difficult. These sub-standard developments are "the Achilles' Heel" of suppression efforts in the wildland-structural intermix.

Current law allows local government to apply some controls over old and new lot splits, provided they have implementing ordinances for that purpose. The same planning procedures recommended for improving general planning can probably be used to reduce the fire problems presented by lot-splitting. The key actions are more complete and accurate description of the hazards, prescription of coping policies in General Plans, and design of fire protection improvements. As a minimum, fuelbreaks or fuel reduction requirements could be included in zoning, or incremental upgrading of access and water systems could be made a condition of future sale of any properties.

THE CALIFORNIA ENVIRONMENTAL QUALITY ACT

The California Environmental Quality Act (CEQA) was designed to identify the environmental effects of proposed activities, ways that damaging effects can be avoided or reduced, and to prevent environmental damage by requiring changes in projects. The Act requires the preparation of an Environmental Impact Report (EIR) for any project that may significantly affect the environment. Guidelines for implementation of CEQA are published as part of the California Administrative Code (Section 15000 et seq).

From the standpoint of identifying and mitigating fire impacts in the wildland-structural intermix, three sections of the implementation guides are important. Section 15355 states that cumulative impacts "can result from individually minor, but collectively significant projects" that take place "over a period of time." Section 15358 defines "effects" to include "indirect or secondary impacts caused by the project" even though those impacts "may be later in time or farther removed in distance." Section 15041 gives public agencies the authority to require changes "in any or all activities of a project" to reduce impacts.

If these Sections are considered in context with earlier discussion (ability to require off-site improvements, "linking" open space dedications for public protection, and reviewing projects in relation to adjoining areas), planners and fire services apparently have underutilized their applications. Clearly. more energetic application of these existing legal prerogatives would improve fire protection systems in the intermix. Also, the same efforts required for general planning improvements and the incremental upgrading of lot-split problems apparently would serve to enhance CEQA applications.

IMPLEMENTING CHANGE THROUGH STRATEGIC FIRE PLANNING

Strategic Fire Planning is the process of developing area-wide (i.e., major watershed, local jurisdiction, or critical community) systems of fire defense improvements. Improvements would include--but not be limited to fuelbreaks, other fuel reduction areas, greenbelts, and necessary facilities such as helispots and fire stations. Improvements should be integrated and interrelated in complete systems where possible and not be designed as individual projects. Primary goals would be to provide maximum public safety, property, and resource protection with the fewest possible suppression forces. Design will vary with terrain and development conditions, but the improvements should provide perimeter defense capabilities for areas no larger than 300 acres; some conditions could require designs to protect as little as 10 to 30 acres.

Strategic planning is not a new concept. The intent and practice of strategic planning have existed for over 50 years; however, those efforts were not always successful. Landowner resistance, government inertia, budget and personnel limitations frequently debilitated improvement implementation. The combined resisting forces, compounded by accelerated development in the wildlands, has led fire services to view the concept with pessimism. Past and present failures create strong suspicions that future efforts will also fail.

There are two significant differences between past failures and what is suggested here. The first difference is the process of implementation. Past fire service efforts started at the end of the local planning process rather than at the beginning. Fire agencies designed their projects and then attempted implementation "on top of" existing local planning and zoning regulations. Agencies were forced to appeal for approval of their projects because they were not integrated into the planning processes authorized by law. Local government was not a partner in implementation. If the legal opportunities described in this paper are used, this difficulty can be overcome. Strategic planning can be integrated into the body of the planning process, starting with analysis of General Plan and Safety Element situations and impacts, and proceeding through zoning and environmental mitigation.

The second difference is between past and potential funding. With the exception of some successful case-by-case applications (acquisition of land for facilities, and some lesser fuelbreaks, primarily) fire agencies have assumed almost total responsibility for financing construction and maintenance of all strategic improvements. Lawmakers have resisted funding the ever-increasing workloads with public monies, and the agencies find themselves far behind in both building and maintaining improvements. Most smaller agencies (fire districts and local departments) have not even considered strategic improvements because of the problems encountered by their larger colleagues. This paper has shown that fire protection improvements need not be the exclusive burden of the fire services. With the proper impact analyses and local planning ordinances, developers and landowners can and should take over the majority of costs.

Strategic planning is the key to mitigating the wildland-structural intermix problem. But the strategic planning in and of itself is not enough. The entire local land use planning process must be used as the initiation and implementation vehicle.

RECOMMENDATIONS

Coordinated action in three areas of endeavor is needed. The action is needed now, to assure that the rapidly increasing wildland-structural intermix fire problems can be held to acceptable levels in the future. The three areas are described below.

1. Legislation--The basic legal authorities for much of the needed improvement already exists, but legislative <u>recognition of the intermix problem</u> is needed. The California Environmental Quality Act should be clarified to recognize the intermix and to include further definition of off-site and adjoining community impacts. Local governments need the same direction for General Plan guidelines on fire safety as has been given for earthquake and flooding. The State Board of Forestry, Board of Fire Services, Fire Marshal, and the California Fire Chief's Association should be enlisted to assist the Office of Planning and Research in the development of new guidelines. Goals of the effort should be more accurate situation assessment in Safety Elements and preparation of consistent coordinating policies in Land Use, Conservation, and Circulation Elements.

"New" legislation may be needed to correct past omissions and improve fire safety requirements of the Subdivision Map Act. The critical presence of substandard developments justifies strong efforts to amend existing law. As a minimum, incremental improvements to water systems and emergency access should be required whenever substandard properties are sold.

2. Research--Socio-political-economic research is the the most important contribution that could be made in support of fire safety improvements. Lawmakers at the state and local levels need more objective data before they can support positive change. Data must be collected (and presented) on real costs and losses, mitigation and suppression trade-offs, and

policy formation for fire prone areas. In addition, applied, not basic, research is needed to assist fire services and planners with implementation of fire behavior modeling, orthophotographic mapping, and other products that are now resting "on the shelf."

3. Strategic Planning--This effort, supported by legislative change and applied research, needs to begin now to be effective by the year 2000. Fire protection planning must be oriented to the total wildland-structural intermix environment as well as the case-by-case approaches now emphasized. The strategic planning must be integrated into local planning, from General Plans through mitigation requirements.

No other action taken by fire services will be as effective as strategic planning in reducing future fire impacts.

REFERENCES

Amador County. 1985. Amador County General Plan. Jackson, Ca: Amador County Board of Supervisors.

Calaveras County. 1986. Calaveras County General Plan. San Andreas, Ca: Calaveras County Board of Supervisors.

Curtin, Daniel J. Jr. 1986. California land use and planning law. Berkeley, Ca: Solano Press: 169 p.

El Dorado County. 1986. Subdivision design and improvements manual. Placerville, Ca: El Dorado County Board of Supervisors, Resolution 136-86; 52 p.

Mariposa County. 1984. Mariposa County General Plan. Mariposa, Ca: Mariposa County Board of Supervisors.

Nevada County. 1983. Nevada County General Plan. Nevada City, Ca: Nevada County Board of Supervisors.

Placer County. Placer County General Plan. Auburn, Ca: Placer County Board of Supervisors.

State of California Department of Commerce. 1985. County profiles, sources and general information. Sacramento, Ca: Department of Commerce; 116 p.

State of California Department of Finance. 1984. Population estimates for California cities and counties, 1970 through 1980, report 84 E-4. Sacramento, Ca: Department of Finance; 64 p.

State of California Department of Forestry. 1970-1985. Annual statistical reports. Sacramento, Ca: Department of Forestry.

State of California Department of Forestry. 1985. Fire protection plan for state responsibility area forest, range and watershed land. Handbook No. 7000. Vol.1. Sacramento, Ca: Department of Forestry: 86 p.

State of California Governor's Office of Planning and Research. 1985. Planning, zoning and development laws. Sacramento, Ca: Office of Planning and Research; 377 p.

Tuolumne County. 1980. Tuolumne County General Plan. Sonora, Ca: Tuolumne County Board of Supervisors, Resolution No. 682-80.

Tuolumne County. 1983. Tuolumne county guidelines for implementation of the California environmental quality act. Sonora, Ca: Tuolumne County Board of Supervisors, Resolution N. 854-83; 141 p.

Management Response and Needs
(*What are we going to do about it?*)

Gen. Tech. Rep. PSW-10l Berkeley, CA. Pacific Southwest Forest and Range
Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

The Wildland/Urban Interface in 2025[1]

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Abstract: In the year 2025, wildland fire fighting practices have improved significantly over the method employed during the late 1900's. Improved methods for predicting severe fire weather conditions, the establishment of the North American Fire Coordination Center, and the utilization of foam products for both wildfire and structural fire control have significantly changed the methods of fire suppression. An increased awareness of the dangers posed by wildfire has been accomplished through a concentrated effort to educate the public. Buildings are being constructed that afford greater protection, and fuel modification surrounding structures is now required by most state and provincial governments. With the accomplishments achieved during the past 40 years (1985-2025) it's hard to believe that wildland fire protection could become more efficient or effective, but I am sure it will!

In this paper I discuss the wildland/urban fire problem as I see it in the year 2000 and beyond. I have chosen to base most of my projections on the year 2025. Before I do this, I will define the wildland/urban problem, and then look at how we have gotten to the point where we are in 1987. My definition of what constitutes a wildland/urban interface is any area where residential or commercial development is intermingled with flammable vegetation. That vegetation could be trees or brush, or in some cases, even grasses. When this situation occurs it can significantly alter the methods that are used to control either wildland or structural fires. Wildland fire fighters find themselves concerned about structures, and structural fire fighters may have to deal with problems of fire spreading to the wildlands. According to Al West, current Deputy Chief for State and Private Forestry, of the Forest Service, U.S. Department of Agriculture, "our fire fighting costs continue to climb because of the need for more equipment and personnel to save structures." Increasingly fire commanders have to sacrifice control of the wildfire to defend buildings (NW/UFPC 1987). Where are all of these buildings coming from? Looking at the United States in 1945 there were 140 million people living here By 1980 the population had jumped to nearly 225 million, an increase of over 60 percent (Bogue 1985). In the 1950's and 1960's much of this population was centered in urban areas. However, during the 1970's a migration back to the country or at least out of the city centers began. During this time the rural population grew as rapidly as the urban population. Looking specifically at rural counties around the nation's forests, the Forest Service reported a population growth rate of 25 percent. which was higher than the growth rate for the nation as a whole (NW/UFPC 1987).

So in 1987, there is a continuing increase in the population, and an increasing tendency for individuals to want to move from city centers to more suburban or rural settings. Having our dream homes away from city centers, places increased pressure on wildland fire managers on how to effectively deal with an issue that 30 to 40 years ago was much more limited in scope. It also places increased pressures on local governments to provide services, particularly fire protection, at a

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level that wasn't necessary in the past. A good example of this can be found in Virginia where between 1979 and 1984 there was a 75 percent increase in the number of homes built in areas that had wildland fire potential (NW/UFPC 1987). Examples such as this can be found throughout the United States, in New Jersey, Massachusetts, Florida, Nevada, and California. As we look ahead to the year 2025, population projections indicate that there will be approximately 306 million people in the United States. That is an increase of about 36 percent (Bogue 1985). This same rate of growth is projected for Canada which also faces serious problems in relation to the wildland/urban interface. If we can assume that the trend will continue for the increase of population in suburban and rural areas adjacent to the nation's forests, I think we can anticipate more conflagrations such as those in 1985 in Florida and California, and I believe that we can anticipate them becoming more severe.

Another factor to keep in mind when looking at population increase is that over 90 percent of wildland fires are human-caused. With everything staying the same we can anticipate the number of fires increasing at a similar rate. The more fires that have to be dealt with, the greater the likelihood for large catastrophic fires to develop.

So what role do wildland fire managers play in this complex issue of the wildland/urban fire problem? What can be done as we move into the 21st century to minimize the losses from the inevitable fires that will occur?

I suggest that you wildland fire managers, researchers, and educators need to look at the "whole fire problem." You can not isolate yourselves into dealing with only the "pure" wildland fire situation.

The wildland/urban fire protection problem needs to be given the same importance as prescribed fire, smoke management, and wilderness fire. It is not scientifically as nice a package to work on, but expertise in fire detection, fire behavior, fire modeling, and large scale fire management are all areas that need to be addressed in relation to the wildland/urban fire problem.

In the 1970's some excellent work was accomplished by the combined efforts of Federal, State and local fire agencies on the FIRESCOPE project. FIRESCOPE for the first time applied integrated information technology to the fire line and blurred the distinction between urban and wildland fires (Pyne 1982). It was a significant effort that was brought about by a series of catastrophic fires. Unfortunately, it will probably take another event of even greater magnitude to direct the resources and talent to again address this problem with the same level of commitment. What took place in California during the FIRESCOPE project really needs to take place across the United States. An effort to improve local fire fighting capabilities by integrating both wildland and urban fire fighting forces so that they are able to effectively work together to prevent and suppress wildland/urban fires. Efforts must also be made to encourage the utilization of more fire resistive construction techniques and the better designing of communities to minimize their exposure to fire. The use of fuel breaks and other methods of modifying ground fuels near structures must be encouraged.

In many cases this information is currently available, but effective methods for the adoption by local regulatory authorities, or even effective methods for developing awareness among property owners as to the benefits for following such guidelines are not available on a widespread basis. I believe an effort must go forward to develop historical fire and meteorological data that will identify the fire probability in a given area similar to what is done with 50 or 100 year flood designations. With that information local officials can then make decisions based on real data. Currently decisions have to be based on what local fire officials think is the problem.

What will the 21st century be like for wildland fire managers? Well, I am going to take an optimistic view and say that significant strides will have been made. A new attitude will prevail concerning fire. However, this attitude will not have come about just because of a newly enlightened citizenry. Unfortunately, as has been the history in the United States a catastrophic event will have occurred sometime between now and the year 2000. This event quite possibly will be in the eastern portion of the United States and will be our Ash Wednesday--the series of fires in Australia in 1983 that caused 77 deaths, destroyed 2528 homes and burned more than 840,000 acres. From this event, citizens will clamor for better protection, politicians will see the value in leading the way, and finally a concerted effort, FIRESCOPE Part II will be underway. From this will come evidence that fire fighting organizations, both wildland and structural, must work together to be effective. The development of a well funded, nationally coordinated, fire prevention program will begin. Better detection methods. improved fire suppression techniques and equipment will be developed. Local communities will adopt stricter regulations concerning building, design, use of fuel breaks, and combustible roof coverings. Citizens will become more involved in neighborhood organizations to assist in fire prevention and in taking more responsibility for their own protection.

At this point, I would like to look into the future and develop a short scenario that would look at wildland/fire management in the wildland/urban interface in the year 2025.

A North American Fire Forecasting and Coordination Center has been established jointly with Canada. At this center, potential conditions throughout North America are continually monitored. Predictive models have been developed that allow fairly accurate forecasting up to 90 days before the development of high or extreme fire conditions.

As specific areas indicate the possibility of severe fire conditions developing a National Fire Prevention Coordinating Team is activated. This team will go into an area and assist local fire officials in implementing intensive fire prevention awareness campaigns targeted at the immediate problem. One of the tools they will use is the Ignition Management Plans that have been developed locally. These plans will identify the areas and the audiences that fire prevention information must be targeted. This process evaluates three factors, risk, hazard and value. Subsequent prevention programs can then be focused on the potentially more damaging ignition problems.

The Forecasting and Coordination Center will continue to update the data being received by satellite and from field stations, to continually refine their forecasts. As the severe fire conditions become reality, specialized equipment and personnel will be brought in to augment local fire suppression forces.

One of the key pieces of equipment will be the specially designed short-takeoff and landing aircraft that does not need to work from airports, but can be located in the targeted area. Operating with a ground tender the aircraft has a 1000 gallon capacity, and uses a foam concentrate for increased effectiveness.

Again as the fire weather severity increases, the movement of equipment and personnel is further concentrated to areas with the highest risk of ignitions. A Cray Computer is used to maintain seven major data bases; (1) equipment and personnel inventories from throughout North America current to the hour; (2) fire history to the hour; (3) lightning location data to the second; (4) historical, current and forecasted weather; (5) fire weather indices; (6) fuel types and topography to 50 meter grids; (7) and a fire modeling system that immediately starts modeling any ignitions as soon as they are reported. With this information, limited fire suppression forces are concentrated in areas that are most susceptible for ignitions and also present the greatest values at risk.

Along with the adoption of better community designs, better building materials and a public with an increased awareness of the need for fire prevention, the wildland/urban interface problem is controlled to an acceptable level.

In conclusion, I would like to point out that the items discussed in this scenario, although speculative, are all available to some degree now. Russ Johnson (1987) of the San Bernardino National Forest has developed a proposal for a National Fire Prevention Mobility team. The ignition management planning process has been developed by Bill Bradshaw, Bill Smith, and Jim Page (1987) of the Forest Service, U.S. Department of Agriculture. The decision support system has been developed by the Canadian Forestry Service and is currently being used on a trial basis in some parts of Canada.

I urge wildland fire managers, researchers, and educators to keep in mind the issues of the wildland/urban interface. If ignored, they will over take you at some point. It is necessary to get out and develop relationships with your colleagues in the structural side of the fire business, and it will only be through the extensive development of cooperation that this problem can be addressed. Improved methods also have to be found to implement the excellent work that has already been done.

I am optimistic that as we go forward, this serious fire problem will be minimized.

REFERENCES

Bogue, Ronald J. 1985. The population of the United States, historical trends and future projections. New York: The Free Press.

Bradshaw, William and others. Ignition management planning process. Unpublished draft supplied by author.

Johnson, Russ. 1987. National fire prevention mobility operations guide. Unpublished draft supplied by author.

NW/UPFC 1987. Wildfire strikes home. Report of the National Wildland/Urban Fire Protection Conference. Quincy, MA: National Fire Protection Association; 90 p.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Shared Resources[1]

David B. Butts[2]

Abstract: Wildfires do not respect property boundaries. Whole geographic regions are typically impacted by major wildfire outbreaks. Various fire related resources can be shared to solve such crises; whether they are shared, and how they are shared depends to a great extent upon the rapport among the agencies involved. Major progress has been achieved over the past decade largely through the adoption of some formalized processes, such as the National Wildfire Coordinating Group. More progress can be made on into the 21st century at the local, state, and national levels if managers will support the cost effective use of shared resources in the attainment of wildland fire management objectives.

The topic "Shared Resources" at first struck me as being somewhat out of place in the setting of the 21st century. The more I explored it however, the more it appeared to be the epoxy that will bond us together and enable us to move efficiently into the future.

Before launching into this discussion of shared resources, it is important to define the term "share." According to Webster, a share is "one's full or fair portion," (Webster 1985). We are dealing with portions of a whole, whole being all wildland fire management resources.

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THE ABILITY TO SHARE

Individual agencies must first establish a process that enables them to meet their internal needs for wildland fire protection. The normal year fire planning process identified one way of normalizing fire activity to provide, at least statistically, a means to target realistic numbers of fires per year for planning and programming purposes. That would suffice in field areas for their internal fire suppression needs in most times. However without expansion to address the ability to handle the worst case scenario in exceptional years, the process would fail to perform. So, in addition to the normal fire year process for field areas of an agency, there also needs to be an additional regional/national investment in worst case scenario. A national normal fire year, if you will, would identify those resources that must be available somewhere in the system, to back-up the field areas in their worst fire years.

Only after agencies have managed to obtain a reasonable degree of protection for their own lands, can they seriously look at the sharing of some of those resources. At this point they have merely laid the groundwork upon which the concept of shared resources rests if it is to serve local, regional and national needs. Regardless of the administrative level of the sharing activity, the principles are the same.

Finally, to manage shared resources, the partners in this process must have agreed to form a whole body of wildland fire personnel and resources which may then be shared among the group during those times when demands exceed individual capability. The magnitude of individual sharing is not as important as the intention and effort to share.

EFFECTS UPON FUTURE SHARING

There are as many futures as there are thinking people who plan ahead. We need to set the stage for a future against which we can plan, before we can make forecasts and develop solutions to problems that may evolve. Sideboards are needed if we are to be able to focus our attention and our energy into productive channels. The Symposium on Wildland Fire 2000 should help provide that focus. Futurists such as Naisbitt warn too that having met and planned is not enough (Naisbitt 1982). We must also keep alert for changes in our assumptions that may call for revision of our actions over time.

In reality, we in wildland fire management may have it relatively easy. When compared with those bodies that must attempt to project international political ramifications to the year 2000, wildland fire appears much more simple and manageable. While we, in the wildland fire community, may proceed on these assumptions, we must be mindful of the fact that such things as world population pressures, war and peace, and the economy of the United States and of the other nations of the world may be controlling factors in management options and problems in the future.

Let us reflect a few moments on the activities of the last 13 years before turning ahead to the next 13 years and beyond. We are today reaping the benefits of those investments made a little over a decade ago. They are crucial in the discussion of shared resources.

The wildland fire crisis of 1971 in southern California, jarred the wildland fire community by its magnitude and jurisdictional complexity. The intensified interagency activity fostered changes in technology and the pulling together of federal, state and local fire entities.

Two major organizations evolved in the seventies that created our ability to share effectively on a national scale today: the Boise Interagency Fire Center (BIFC) and the National Wildfire Coordinating Group (NWCG). BIFC evolved in recognition of the need for interagency operational coordination. The expandability of seasonal operations there in response to seasonal fire demands have facilitated its national operations. It has also attained international recognition for response to emergencies. The three original federal partners, Bureau of Land Management, U.S. Department of the Interior; Forest Service, U.S. Department of Agriculture; and National Weather Service, U.S. Department of Commerce--have since been joined by the National Park Service, Bureau of Indian Affairs, and the Fish and Wildlife Service, all of the U.S. Department of the Interior. The Office of Aircraft Services. U.S. Department of the Interior has also moved onto the base.

Heart of the national interagency activity at. BIFC has been the Logistics Support Office (LSO). since characterized as the National Interagency Fire Coordinations Center (NIFCC). During critical national mobilization such as that in 1985 and 1986, it is expanded by the land management agency managers who serve as the National Multi-Agency Coordinating (MAC) Group.

The second entity, the NWCG, which operated informally from 1974 to 1976, until, it was chartered by interdepartmental agreement. it nonetheless made significant progress from the start providing the critical national interagency policy framework for shared action. The Training Working Team and the Qualification and Certification Working Team of NWCG, lead the landmark activity which enabled us to exchange personnel among agencies on a national scale.

The evolution of the high quality fire suppression (S-course) training series provided a vehicle through which all of us could train against the same standards and in the process learn to work with one another. Yes, there were problems with the implementation of NIFQS, the National Interagency Fire Qualification System, but it and the S courses did provide the basis of national interagency cooperative activity for most of the last decade.

Not all the products that will be available in the year 2000 and beyond are visible today, but their roots will be in the technology and the organizations of today. Both a policy framework and an operational process are essential if future sharing is to be feasible.

Looking ahead we will have a difficult time projecting the direction of this economy and all options that will be available to us. However, futurists such as Naisbitt (1982) in Megatrends, appear to agree that the rate of change and the magnitude of change will increase rather than decrease as we move on into the 21st century.

It is timely here to also remember that wildland fire management is not the dominant activity of any of the federal land management agencies. It is a support program providing protection for their resources in the context of agency mandates and implications for the future. The fire management program will move as the agencies move.

We live with the idiosyncrasies and wide variability of weather and fire occurrence. Notwithstanding, the magnitude of wildland fire occurrence and its timing are significant factors influencing our ability to muster support from our agencies and from the public in general. We passed through wetter than normal years, 1982 and 1983, and felt the support for fire protection wane; only to enter 2 years back-to-back, 1985 and 1986, which would be classed as crisis years! The degree of support which we may receive in the future and our ability to perform will be directly dependent upon the interpretation of our potential contribution to agency programs. The weather and associated fire occurrence between now and the turn of the century might significantly alter our ability to attain the goals envisioned at this symposium.

We might also reflect for a moment on the tenuous nature of shared resources and of our commitment to the future. The tendency is to "pull in one's horns" when times are tough and to accept the risk of disappointing partners rather than to muster an additional defense of the need to maintain those partnerships as cost-effective options.

There are a few assumptions about the future from which I will proceed in my discussion of shared resources. Fire protection is predominantly a public function. The public can be expected to continue not only to anticipate but also to demand fire protection. We also see throughout the United States today that the public is most interested in obtaining the most for its dollar. Well founded, economically smart management will be the expected standard.

THOSE SHARED RESOURCES

With the crisis years, of 1985 and 1986, still fresh in our minds, there is little doubt about the contribution made to those numerous project fires by shared resources. Nor is there any question that the most frequently shared resources were personnel. Those skilled, trained, physically fit and equipped fire personnel upon which we ail rely, are the backbone of the shared resources today and undoubtedly will be on into the future.

Our ability to develop qualified, mobile and well-supported overhead management teams will be a significant factor, determining our success in managing severe wildland fire outbreaks. They need to be supported by organized crews of firefighters who allow us to get the job done on the ground. All the technology in the world is not likely to supplant the ability of people to complete the suppression of fires in wildland fuels.

In addition to the personnel on the fire, we cannot forget the importance of those individuals who facilitate the development of those skills and knowledge. They develop the essential quality training materials. These subject matter experts from all the agencies, allow us to pool the best talents in the entire wildland fire community to generate those courses. In addition to the training packages, we have the cadre of instructors who bring not only the wildland fire talents with them, but also their instructional and educational skills and knowledge.

In 1985. more than 20,000 people were mobilized for the wildland fire activity in the western United States. Resources were taxed but there were still reserves of personnel available that could have been brought to bear should conditions have further deteriorated. An emergency training program was even mobilized to expand the ranks of firefighters.

The complementary side of the shared resource system involves all those facets of technology that have become an integral part of wildland fire management today. Whether they be the engines, helicopters, retardant aircraft, the fire weather/fire danger network which we use in our planning, or the infrared sensing aircraft which allow us to see our problems more clearly, they all are essential facets of the wildland fire management program today.

Looking to the future, the particular contribution of those various facets of technology will undoubtedly change. The physical availability of certain of the components likewise will change. There really is a limit to how long World War II vintage aircraft can be sustained! However, the delivery of retardant to fire will undoubtedly persist even though the mixture, method of delivery and the particular hardware in which it is transported may change significantly.

Today we are, particularly at the local level, already sharing resources on prescribed fire activity. Personnel from several agencies are grouped together to execute prescribed burns in given geographic areas and to minimize the cost of transporting personnel of a single agency over much larger distances. This has particular significance when carried out under the uncertainties of hitting a narrow prescription window.

There are also some changes in the character of shared resources which are on the horizon. The need for and development of, an improved wildland fire communications system has already been identified as a research and operational need if we are to effectively run wildland fire management on a national scale. The world of instant national media coverage, public involvement and all the layers of political involvement in the sharing process require good information, instantly!

Along with that system is the possibility of networking our information systems. The current generation of hardware has its obstacles, however the intent of manufacturers and users alike is to overcome those obstacles and physically permit a considerable increase in the exchange of knowledge and data among wildland fire partners.

Probably one of the newest and most promising resources to he shared in the future will be that of human intelligence. Not just one-on-one, but through the merger of computerized systems and the contributions of expert knowledge. Expert systems and artificial intelligence may permit us to provide an opportunity to capture the intuitive expertise of an individual and make it available to others at that time and also to other generations. Latham (1987) expands upon the potential of this evolving facet of our fire resources. A big factor in the future sharing of present expertise will depend upon our ability to generate a process that will be viable over time to trigger the retrieval of the stored "expert" solution.

This too has potential for international sharing as further indicated in a recent article from the Petawawa National Forestry Institute in Canada (Kourtz 1987). They too are pursuing both artificial intelligence and natural language processing.

The specific resources to be shared will be dependent upon the technology and innovation of fire management personnel and researchers working today. The possibilities are virtually endless, given support and encouragement for new innovations and development.

HOW WE SHARE

Sharing does not just happen. While we may be able to operate on an impromptu basis for a short period of time or infrequently, the primary vehicle through which sharing takes place has some formalized structure. Let us examine the process of sharing itself and how it can be conducted and what inhibits its conduct.

Informal sharing is always an option in any emergency activity. When a call goes out for assistance during a crisis such as wildland fire, the agencies in the area generally respond. That response is predicated upon obligations and public acceptance. Such informal response, by and large, is short-term in nature and on a very localized scale.

It also must be of an infrequent nature, in that frequent exercise of a call for help will soon lead toward one of two solutions: either a refusal because of the excessive demands, or a proposal for a formalized relationship to guide future requests of that nature.

In addition to those other characteristics, informal responses must be perceived as being in the public good. They must be politically expedient. The act of assistance itself, which may have questionable legal authority, will be overlooked because of the accomplishment of the good deed for the public in general. That credit for accomplishment wears thin very rapidly upon the repeated exercise in the absence of a more firm political and financial commitment.

The more typical process and the backbone of all large scale shared resources, rests upon a legal framework. That framework also is indicative of the committment to cooperate in advance of a crisis. That permits significant preparations which then facilitate the actual sharing of the resources when an incident occurs.

The federal. wildland fire community relies very heavily upon a national interagency agreement as the umbrella under which we all share our resources. A similar agreement exists for the National Wildfire Coordinating Group which also has its official origin in an interdepartmental agreement.

At the local level the typical mutual-aid agreement among urban departments is also characteristic of the procedures by which independent, side-by-side agencies can join to their mutual benefit.

In recent years we have seen that the process of sharing of wildland fire resources knows few bounds. Local, state, regional, national and even international resources have been exchanged on wildland fires throughout the world.

As the scale of the operations increases, the role of the economic factors becomes more and more important. Obviously large numbers of personnel are not normally shared on an international scale. Specialized skills, special equipment and unique contributions are most often exchanged.

Probably the best candidate for improved sharing on an international scale is the knowledge of wildland fire management. Personal knowledge of techniques, strategies and tactics for wildland fire management is a common denominator for worldwide sharing.

The West German government has sponsored two international symposia since 1980 on combatting wildfires from the air. At the last session they expressed a sincere interest in furthering such international exchanges of knowledge and skills in regard to the management of wildland fire.

WHY SHARE?

We have all seen or heard of individual unit managers in our own agencies that were reluctant to make some of their resources available to their peers in a time of need. The question of "Why should I share?" will continue to be raised in the future. Such reluctance is also a part of human nature. Each manager is responsible for his or her portion of a program and is expected to maintain the ability to meet all of the needs and demands that have been placed upon them. Releasing some of their resources to accomplish emergency needs of others, in essence means relinquishing some of the goals or objectives of the lending institution. Hence it is essential that the next, <u>and</u> the next level of supervisors all support the process. All levels of management need to recognize the fact that while one unit may share their resources with another today, the donor unit will probably be a recipient of the shared resources from other managers at some unforeseen crisis in the future.

Two factors stand out as the bases for sharing resources. The first of these is good economics. We would all like to have enough funds and resources to maintain a high level of preparedness every year within our agencies. However, reality will force us to a more modest level of preparedness. We may use a planning process or an economic analysis to determine what that level is, but it will be a conservative figure.

With access to a process of sharing, that conservative level can be pooled when needed and brought to bear on critical fire situations such as we have seen in 1985 and 1986. No one unit or agency in the system would have been able to provide that magnitude of resources in that timeframe. However, through shared resources. major fire activity in widely scattered geographic regions has been handled appropriately and cost-effectively, with those resources returning to their home bases for use another time at the end of the emergencies.

This sharing provides an additional degree of flexibility, the second major factor, beyond that which the same level of locked-in resource allocation could provide. The very nature of wildland fire itself requires that we retain a process that is flexible and responsive to the variations of fire seasons from year to year, region to region and virtually from day to day.

An additional factor is significant in major fire outbreaks. The reality of wildland fire as a common threat to a group of political entities in a given geographic area prompts mutual response. Even in the absence of coordinating agencies, the large wildfires in the early part of this century prompted emergency community action.

When a geographic region experiences one of these critical fire danger episodes as the Southeast and Northwest did this last year. all of the political entities in those areas are galvanized into action to make the most Of the resources they have available and to overcome the obstacle that may have existed in normal times. Good preparations for sharing make it even more effective!

CLASSIC INSTRUMENTALITIES FOR FUTURE SHARING

There are three complementary instrumentalities that have the potential to make even more significant contributions to wildland fire management on into the 21st century. Undoubtedly they will undergo refinements and improvements over time. They play a complementary role to one another. The National Wildfire Coordinating Group (NWCG) is a policy-setting body which provides a framework. Operational coordination ties together regional and national operations, and lastly the National Interagency Incident Management System (NIIMS) puts those policies into action on wildland tire incidents. Together they can provide a significant conduit through which resources may be shared locally, regionally, and nationally and be managed effectively.

I have been privileged to serve on the NWCG along with fellow fire managers from the other four wildland fire management agencies and representatives of the National Association of State Foresters. There has been a flow of personnel through those chairs over that decade. and in spite of the turnover, the underlying commitment of the group remains: the joining together in an effort to create cost effective, quality fire management.

The Creed of NWCG says it best:

> "We believe the goal of effective wildfire management is best served through coordinating the resources of all fire management agencies, irrespective of land jurisdiction.
>
> "We believe in the concepts of full partnership, trust and mutual assistance among fire management agencies.
>
> "We strongly support professionalism in all facets of fire management.
>
> "We strive to bring the best talent available to bear on vital issues in a timely manner, irrespective of agency affiliation.
>
> "We strive for economy, efficiency and quality in all our activities, and practice concepts of total mobility, closest forces, and shared resources without geographic limitations.
>
> "We constantly search for areas of agreement to further the effectiveness of the wildfire management program."

The products and details that are developed on behalf of the NWCG are largely generated by the technical working teams it sponsors. Those experts, shared experts, from federal and state agencies enable the wildland fire community to pool its best talents and focus them upon the solution of specific problems. Frequently the working teams also reflect a composite of technical, managerial and research personnel that allow a synergism to prevail and to foster an innovative process to the benefit of the program. Every one of these teams epitomizes the concept of shared resources in that agency and geographic contributions are also reflected in the assembly of these teams.

One of the subtleties is not necessarily apparent in regard to the NWCG is the process by which it progresses. The NWCG does not have the direct power to implement any programs. Independent agencies work toward a common shared future. The programs espoused by NWCG are carried back to the individual agencies by the members and implemented through individual agency directives. The crucial contribution of NWCG is the generation of a concensus solution among the agencies on processes and procedures, strategy and technological products that reflect a best blend of the needs and desires of all the agencies. It is in fact a subtle process which is very dependent upon the rapport among the individuals representing their agencies and associates.

There must also be an operational aspect of sharing in addition to policy and procedural solutions. The last two years, 1985 and 1986, attest to that fact on an interregional scale. The National Interagency Fire Coordination Center and the MAC group at BIFC serve that national role. It is through this process that total mobility of the shared resources can be achieved. Resources from regions unaffected by critical fire danger are funneled into those regions in need.

Regional coordination is a critical operational link. In most years resources exchanged locally or within a geographic region is sufficient. It would be simple if it were not for the fact that no two land management agencies have the same regional boundaries. Regional personnel must also develop a consensus on boundaries and procedures if this intermediate operational step is to facilitate rather than obstruct sharing.

Finally, and the real reason for the entire elaborate process, we get out on the ground with the line manager of the land and its natural resources. Those line managers need an operational system that works in the real world of fires, program accountability, autonomy, and sharing all rolled up into one crisis situation. The National Interagency Incident Management System was built for just that reason (NWCG 1983).

The system tends to be overlooked, with the attention going to the operational facet, the Incident Command System (ICS). That is a grave error! After adequate preparations for the occurrence of an incident through an active dialog and commitment among adjacent managers, only then can ICS be implemented effectively. Some dissatisfaction has been erroneously attributed to ICS when it really was caused by a failure to fully prepare the whole parent management systems, NIIMS, of which ICS is only one part!

Management by consensus is not easy, in fact it may be one of the most difficult management styles to achieve. It requires a constant weighing of needs and opportunities, give and take, against the backdrop of a varied group of users ranging in size, mandate and jurisdiction. The accomplishments to date are indicative of the fact that the process can work.

THE ROLE OF MANAGEMENT IN THE FUTURE OF SHARED RESOURCES

Earlier when I discussed the process of sharing and its relationship to agency resources, it was obvious that management drives the sharing process. Management in this sense has two forms; that of agency management per se, which runs the entire spectrum of management activities related to the agency mandates, as well as the fire manager who is directly involved with the fire resources and the degree to which they can or may be shared.

In that sense the role of management in the successful use of these resources is not unlike any team sport. All of the partners must contribute their skilled resources to the common good, consistently and energetically if the team is to be successful.

Shared resources are managerially dependent. They rely entirely upon the exchange of those resources among willing partners. The comfort level of this process can be elevated significantly by a structured process and advance agreements on how that process is to function.

CHANGES IN SHARING

The wildland fire activities of most of the federal land management agencies and many of the states have evolved from a pure fire control organization into fire management organizations. As such, one of the changes in sharing that is expanding significantly at the present time is the use of prescribed fire. If there were an activity where shared resources are ideal if not essential to its economic feasibility, prescribed fire would come close. The necessity to minimize costs and to have a very responsive aggregation of personnel that can execute prescribed burns when the weather cooperates, makes this area fertile ground for the use of shared resources toward a common goal.

The added complexity of smoke management and its group of predominately urban/atmospheric players, further supports a shared resource approach for resolution. The ability of the land management agencies to continue to use prescribed fire will largely depend upon the success of that process.

Another change that might evolve in the forseeable future, would be participation by additional players in the natural resource management/wildland fire arena. There are two that are not readily thought of when wildland fire is mentioned, however, they are two of the largest landholders in the federal sector and are not presently represented. They are the Department of Energy and the Department of Defense. Rarely does a year go by without involvement of their land in some significant wildland fire activity upon which personnel from one of the land management agencies or states is involved. The extent to which they participate and the vehicle by which they would participate is yet to be defined.

The last, but not least, arena in which changes will take place is in the wildland/urban interface. The initiative prompted by the actions of the National Fire Protection Association, the U.S. Fire Administration and the Forest Service will raise the visibility of this issue and its associated demands on the wildland fire protection community. It will be virtually impossible to resolve this issue in the absence of shared resources and technology. This will compound even further, through the merger of tactics for structural and wildland fires if the problem is to be resolved.

FUTURE SHARING IS POSSIBLE, IF...!

For the wildland fire community to be successful in the future, we must perpetuate the processes that permit us to share. All the protection agencies involved need to be a part of the system The solutions to the problems that will arise need to be addressed so as to benefit all of the partners.

In addition to the umbrella policies and procedures among all of the partners, we need to have common national, regional and field operations, through which we can handle the fire incidents as they occur. The design of that operational program needs to provide national consistency, cost effective total mobility and yet the ability to adapt operationally to regional and local idiosyncrasies of climate, organization and politics, and use of closest forces.

POSSIBLE = PREFERRED = PROBABLE?

The more partners in the system, the greater the risk of exceptions to the "possible" solutions. Even though that may happen, major gains can still be made beyond the status of sharing today, particularly at the state and local levels.

The wildland/urban interface represents a major new opportunity where the effective use of shared resources can expand greatly, out of necessity.

The probable future will, be less than the possible and preferred future only to the degree that managers fail to share. A continued high level of commitment and search for more effective ways to share could bring the "probable" quite close to the "possible" and "preferred" goal. We, as program managers can make that happen.

REFERENCES

Kourtz, Peter. 1987. Artificial intelligence applications to forest fire management. Forest Fire News. North American Forestry Commission.

Naisbitt, John. 1982. Megatrends. Warner Books Inc.; 290 p.

NWCG (National Wildfire Coordinating Group). 1983. National Interagency Incident Management System. Unpublished.

Webster's Ninth New Collegiate Dictionary, 1985. Merriam-Webster. 1563 p.

Latham, Don J. 1987. Artificial intelligence applications to fire management. [These proceedings].

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Planning the Fire Program for the Third Millennium[1]

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Abstract: The fire program planner faces an increasingly complex task as diverse--and often contradictory--messages about objectives and constraints are received from political, administrative, budgetary, and social processes. Our principal challenge as we move into the 21st century is not one of looking for flashier technology to include in the planned fire program. Rather, we must give major attention to the development of a better, more effective understanding by politicians, administrators, and the general public of the fire program alternatives available, their risks, and their real social, environmental, and economic costs and consequences over time.

Looking ahead to define the future of fire management 10 to 20 years hence in this country is a risky endeavor at best, as a look back at 80 or more years of history will confirm. The problem of forecasting the probable vector of current trends in both fire management capability and need is compounded significantly by a sort of schizophrenia that seems to dog the attitudes not only of some people in the fire organization but also of those in other administrative and legislative roles as well. This is the compulsion to seek a "state-of-the-art" status with technology on one hand while simultaneously clinging to the old, comfortable policies, objectives, and practices for fire protection in the wildlands.

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Despite all the best upfront intentions, when the fire bell goes off there is still a tendency to revert to old ways: fire workload is measured and protection "need" based on what we have done, rather than on what we should be doing; good outcomes are presumed to have flowed from good decisions, and are seldom examined critically to see if they instead occurred in spite of bad ones; acres burned (often described as acres "destroyed") are used as a universal descriptor of the magnitude of fire problems; and the interest of the public, budget analysts. and legislators in funding fire programs awakens anew--albeit briefly.

Our first challenge for the future, therefore, is one of clearly identifying political and social expectations for the wildland fire program. And we need to be sure we are identifying real expectations, not labels and concepts which later will be found to have no substance. From these, organizational goals and objectives, both short and long term, must then be explicitly defined. Then--and only then--can the planner develop the appropriate array of alternatives and associated probable consequences from which the preferred course of action can be selected.

LESSONS FROM THE PAST

Since the inception of substantive formal wildland fire programs around the turn of the century, the development of policies and objectives for protection, and the subsequent planning of a program to meet those objectives, has gone through a number of rather distinctive phases. Pyne (1982), using the Forest Service as a model, identifies four major eras which span the time to the present, each with its own characteristic targeted fire problem and responsive policy and fire control emphasis.

While there is, in fact, some uniqueness to each period, there are also commonalities that flow across time, commonalities that are important to an understanding of how best to consider and plan for the future.

A basic issue, which emerged early and with which we still struggle today, is that of the economics of fire protection. The establishment of the national forests led naturally to the recognition of the need to provide fire protection on those lands. The numerous major fires of 1910 quickly lent some substance to the economic implications of that protection decision. The decision that a systematic approach to fire protection was needed to deal with costly (from a suppression perspective) large fires raised an immediate issue of how much protection was enough. Headley's proposal in 1916 to use the concept of minimizing cost plus loss provided the apparent foundation for a rational planning approach. But application was another matter. First, realistic quantification of potential losses (or even actual ones, for that matter) was difficult at best. *In situ* tangible values therefore tended to become the principal determinant for setting protection priorities. Second, the mere presence of an organized protection force did not preclude larger, costly fires, especially in relatively lower value, lower priority areas. The result was an inability to plan an effective program that met the organizational objectives as they had been stated.

The lack of success that this economic-based approach had in planning the appropriate fire organization helped to bring about a fundamental change in fire protection force objectives in the 1930's. While the reduction of fire costs and losses remained a goal, its attainment was to be achieved through a more direct objective: control all fires promptly while small. Both the high suppression costs and resource losses attendant to large fires would thus be precluded. Fire planning could readily address this objective and identify with reasonable confidence the kind and amount of the fire protection organization that could be expected to achieve it.

The problem with this planning objective was the lack of any attention to the cost component. Not a significant factor in the inexpensive manpower era of the CCC, costs escalated dramatically with rising personnel costs and the introduction of various expensive technologies beginning in the fifties. By the seventies, the process, in retrospect, was virtually out of control. The Forest Service 1972 fire planning project (which was based on the 10 am control/l0 acre size standard) identified a needed fire organization with an annual budget of some $235 million. This was more than four times the then current presuppression funding of $53 million. By 1977, the presuppression budget had risen to $143 million as implementation of the 1972 plan proceeded (Gale 1977).

That this rise in budgeted funds was not accompanied by any identifiably significant increase in program effectiveness, or by a corresponding decrease in emergency fire suppression expenditures, was noted by both Forest Service management and the Congressional appropriation committees (USDA Forest Service 1980). Two actions significant to the direction of current and future fire program planning resulted. First, the Forest Service undertook the development of a fire management policy that tied fire protection objectives to planned resource management direction and expected fire consequences, rather than to an arbitrary universal time and size control standard (USDA Forest Service 1977). Second, the Congress, faced with rising deficits and looking more closely at agency expenditures that produced no tangible or social outputs, directed the Forest Service to conduct a cost-benefit analysis of both presuppression and suppression activities, and to use that analysis to develop and support future fire program budget submissions (USDA Forest Service 1980).

The outcome of these efforts was the reintroduction of an economic efficiency criterion into the fire program planning process. National policy now required that fire program development and execution to be based on minimizing the sum of costs plus the net change in resource values due to fire, consistent with planned land and resource management objectives (USDA Forest Service 1983). Planned fire presuppression and suppression actions in terms of kind, amount, and timing could now be conformed to expected outcomes based on costs and benefits for individual local situations. For the legislator and the agency manager, the process also at last provided a reasonably objective measure of the probable physical and economic consequences of protection program alternatives, information which heretofore was unavailable at least on a macro scale.

An obvious concern is how the current version of the "cost plus loss" concept differs from that applied unsuccessfully in the 1920's.

While quantifying the economic impacts of fire on some resources is still something less than an exact science, agencies at least now have some rational approaches available. For example, values developed for the Resources Planning Act (RPA) process provide consistency among planning units when estimates must be used in lieu of market data. -Planners also now have a validated analytical tool in the National Fire Management Analysis System (NFMAS). While having definite limitations, the process does provide an effective means to systematically integrate resource values, resource outputs, fire effects, probable fire activity, and fire program alternatives to produce and display planning unit-specific information (as well as regional and national program aggregations) on the expected economic and other consequences of each alternative (USDA Forest Service 1980).

This change from fixed protection standards that mandated prompt control of all wildfires has not been limited to the Forest Service. The other federal wildland management agencies as well as a number of states also have moved toward consideration of economic efficiency information in the protection decision process.

Economics, of course, are not the only reason for these shifts away from planning to rigid suppression standards. When resource management objectives are considered in the development of fire management objectives, the resource benefits from fire can provide an equal if not greater inducement for permitting flexibility in suppression action under appropriate circumstances.

LOOKING AHEAD TO 2000

Recognizing that the past is prologue, we turn now to some thoughts on what the future may hold in the way of wildland fire program requirements, and their implications for program planning. Given current trends, there are a number of significant changes taking place that are going to materially affect the wildland fire management program. Some of those with more direct consequences are:

--increased population
--increased average age
--increased leisure time
--increased mobility

These will contribute to substantial increases in demand on wildland resources. For example, the Resources Planning Act assessment for the National Forests expects over the next 50 years the need for a 50 percent increase in timber production, a 200 percent increase in water yield, and foresees a greater than 60 percent increase in recreation use (USDA Forest Service 1986). Air quality concerns--and associated pressures for severe restrictions on activities that precipitate them--will multiply.

While the rate of migration from urban to suburban and rural areas has slowed in recent years, the spread of dwellings into the fringes of the wildland environment will continue to be significant.

At the same time, these same population changes are going to be generating an increasing demand--if not requirement--for a variety of publicly financed social programs and services at federal, state, and local levels.

The implications of these changes to planning fire programs are obvious: we are going to simultaneously face increases in wildfire occurrence; increases in the adverse consequences of wildfire (and thus increased pressure to provide more effective fire protection); decreased capability to use fire as a management tool; and significant competition from a wide range of high priority, nonfire programs for increasingly constrained budget dollars--all at a time when the cost of personal services is also going to be an increasing problem. Successfully meeting this challenge is going to require creativity, and a willingness and ability to change some old ways.

Already the days are about over when fire protection agencies can invoke the specter of impending wildland holocaust as justification for budget requests. Congress stopped buying that somewhat tired line almost 10 years ago, and States would seem for the most part to be similarly inclined. Fire services are going to have to do a better job first in competing for the budget dollars, and second, in using the dollars they do get. Lets explore some ways to accomplish this.

When faced with the need to look for opportunities to improve program effectiveness, there is a tendency to look first to new technology for solutions. In the main, we are eternal optimists. If today man can go to the stars, surely next month, next year, or next decade we should be able to capture that technology for application to our problem. Newer is better, and keeping pace with the state-of-the-art is a necessity. Now technical progress is certainly essential for effective wildland fire protection. But history would urge some cautions be observed in program selection and application.

First, operationally effective technical advances come about significantly slower than they are expected and planned for. One therefore has to exercise some caution about depending too much on some potential future break-through to solve a current problem.

Second, the mere availability of operational state-of-art technology in no way assures either its efficient or its effective application. The inertia inherent in any organization (and the wildland fire services, with all due respect, are more noted for their reactionary than their revolutionary attributes) tends to operate against the timely, fully effective introduction and use of new ideas. Near term expectations usually become longer term realities.

Third, what is efficient in one application may become an economic albatross if not carefully managed. The airtanker program over the past 25 years is an example. Originally consisting of relatively inexpensive to operate surplus World War II aircraft that delivered loads modest both in size and cost, the fleet and its manner of use underwent an almost insidious metamorphosis. The number of planes grew, and soon larger, expensive aircraft that carried retardant costing several thousand dollars a load became the rule. If some retardant was good, lots apparently was better. As a result, the airtanker program became a major contributor to sharply increased fire suppression costs by the 1970's, and one had to wonder what kind of return we were getting for our money. Analysis of costs and benefits finally provided some needed direction, and in recent years that program has seen significant revision. There may well be other tools showing up in our fire management bag of tricks that. while making good press, may demonstrate similar tendencies. Be on guard not to be seduced by the glitter of their state-of-art technology.

My point is that, while important, technology alone is not the answer to the problems either of today or of the future.

I think there are two major keys to future success, both of which are essential. Both are going to require some changes in attitudes and capabilities of many of today's managers. The first is an increased use of analytical techniques to evaluate programs and technology both before they are implemented, and for monitoring their performance. And these analytical techniques must include an evaluation of the economics, both costs and benefits, of any proposal. Like it or not, economics is the common denominator by which uncommon programs can and will be compared in the political arena. While having a proper economic analysis will not guarantee adequate funding, failing to do one will definitely increase the probability of inadequate funding (MacCleery 1983).

Economic analysis also develops information necessary for setting priorities and making program decisions internally. It provides an indication of the potential costs of meeting protection requirements generated by social or environmental issues, information which can be of major significance in the decision process. A joint analysis in an area where two or more agencies share protection responsibilities will both identify the best protection program for the area as a whole, and provide a rational basis for the equitable sharing of costs. Important today, economic efficiency and cost-benefit data will be essential in the future to identify the appropriate kind and amount of forces and activities for the property and resource values protected, and the consequences of alternative budgets and programs.

Unfortunately, some managers today cannot or will not use analysis, especially economic analysis, in the planning and decision processes. They view the outputs either as inappropriate for evaluating wildland fire protection options, or as potentially threatening to their prerogative to make decisions. Neither view is valid.

Analyses--economic or otherwise--do not make decisions. Rather, they develop consistent, objective information by which alternatives can be evaluated and compared. It is left to the decisionmaker to consider the merits of this information relative to other pertinent factors, and to select the alternative that best fits all the decision criteria.

Some would argue that economic efficiency is not an appropriate factor in planning their agency's protection programs since there is either a legislated mandate to provide equal protection for all lands within their jurisdiction, or that the use of dollar values is not appropriate for the resources they protect. Since none of these agencies is currently provided an unlimited budget, nor do they have protection forces distributed completely and uniformly over their area, someone obviously must be considering the economic costs and benefits of protection along with social, environmental, and political issues. Priorities for past dollar expenditures obviously have been established based on perceptions of fire program costs and benefits. And they will obviously continue to be based on these perceptions--be they right or wrong--until they can be replaced with relevant factual data.

We need to give high priority to developing a better understanding, both by all levels of management and by legislators, of the meaning and use of analytical data in the program planning and budgeting process. We also need to move ahead with the development of better analytical capabilities so that our tools keep pace in the future with ability to use better information. The technology of modelling and expert systems offers some excellent opportunities if--and I stress if--we manage its application.

Finally--and most importantly--even the best analysis and the best technology must have some framework if they are to be properly used. This framework must consist of well-defined, rational organizational goals and objectives against which the potential utility of a program or a tool can be measured before it is selected for implementation. Strategic program expectations must be understood before individual solutions to tactical problems are developed. A new, more costly detection system which successfully meets an immediate objective of locating fires more quickly to reduce burned acreage may well fail a higher order test which mandates a look at marginal changes in overall program cost plus loss.

The varied "best" strategies that have been applied with varied success to wildland fire protection in this country since 1900 have resulted as much from differing perceptions of the problems and their causes as from the differing ideas about the criteria upon which protection should be based. While certainly still far from being all-wise, protection agencies today have the advantage of both historical experience and increased knowledge, and the capability to process the aggregate information these provide. Given the complexities of the current and expected future fire management environment, the need for clear direction is fundamental for any valid planning to ensue. The keystone of this direction is carefully thought out, well-defined fire management program objectives which reflect and integrate the realities of social, environmental, political, and economic requirements and constraints. Management that is able to provide this direction in the future will succeed. The time to start building the capabilities to do this is now

REFERENCES

Gale, Robert D. 1977. Evaluation of Fire Management activities on the National Forests. Policy Analysis Staff Report. Washington DC. Forest Service. U.S. Department of Agriculture; 127 p.

MacCleery, Douglas W. 1983. Analysis, Politics, and Decisions. Unpublished paper delivered at USDA Forest Service Fire Management Analysis Course, Marana, AZ.

Pyne, Stephen J. 1982. Fire in America. Princeton, NJ: Princeton Univ. Press; 654 p.

U.S. Department of Agriculture, Forest Service. 1977. 1978 National Fire Management Action Plan. Washington DC.

U.S. Department of Agriculture, Forest Service. 1980. National Forest System Fire Management Budget Analysis. Washington DC; 29 p.

U.S. Department of Agriculture, Forest Service. 1983. Forest Service Manual, Title 5100, Chapter 5100 Zero Code. Washington DC.

U.S. Department of Agriculture, Forest Service. 1986. A Recommended Renewable Resource Program: 1985-2030. Washington DC; 35 p.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Fire-Danger Rating: The Next 20 Years[1]

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Abstract: For the next 10 years, few changes will be made to the fire-danger rating system. During that time, the focus will be on the automation of weather observing systems and the streamlining of the computation and display of ratings. The time horizon for projecting fire danger will be pushed to 30 days by the late 1990's. A close alignment of the fire-danger rating system with the fire-behavior and fire-planning systems will occur with the release of the second-generation fire model in the late 1990's. Improved utilization of all of these systems will be delayed until more structured approaches to decision making are adopted by management. By 2007, expert systems utilizing real-time direct and remotely sensed weather and fuel moisture data will be on line.

Research to develop a means of evaluating wildland flammability began in the United States more than 60 years ago. Coert du Bois, S.B. Show, E.I Kotok, and H.T. Gisborne dominated the early fire research scene. Six fire-danger rating "meters" were developed between 1930 and 1946 by Gisborne for use in the Northern Rockies. Programs patterned after that of Gisborne were pursued in many sections of the United States in the 1940's and 1950's. John J. Keetch worked on a national fire-danger rating system from 1958 to 1963. By the late 1960's, researchers M.J. Schroeder (U.S.), A. McArthur (Australia), and C.E. Van Wagner (Canada) were setting the pace in fire-danger rating research and development.

Mark J. Schroeder organized the U.S. national program at Fort Collins. Colorado in 1968; I joined the unit in 1970. James W. (Wally) Lancaster, Michael (Mike) Fosberg, R.W. (Bill) Furman, and I worked together until the 1972 version of the National Fire-Danger Rating System (NFDRS) was completed (Deeming and others 1972) and the computerized version (AFFIRMS) on line (Helfman and others 1975, 1978).

From 1973 to 1975, Wally Lancaster and I continued with the NFDRS program at the National Interagency Fire Coordination Center (formally the Boise Interagency Fire Center) with the able help of R.J. (Bob) Straub. R.E. (Bob) Burgan, Jack D. Cohen, and I were the key players from 1975 through 1978. We made the 1978 update of the System (Deeming and others 1977). That work was done at the Intermountain Fire Sciences Laboratory (formally the Northern Forest Fire Laboratory) (Bradshaw and others 1983).

Having "been in the business" for 17 years, looking 20 years into the fire-danger-rating future for this meeting seemed like a reasonable undertaking. However, I sought the views of others with fire-danger rating backgrounds in Canada and the United States, hopefully to balance my own biases. A number of those distinguished people responded and I have "pooled" their "visions" in this 20 year outlook.

For this exercise, I made a sincere attempt to avoid the "Starwars" syndrome; limiting my futuring to the "probable," and tried not to be distracted by the "possible." That was not easy in this bells and whistles era of dial-up color radar, pull-down menus, 80-megabite PC hard disks, satellite data relay, and so on. Neither

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did I intend to restate any of the issues highlighted in my 1983 "Reflections" paper on the development, application, and future of NFDRS (Deeming 1983).

This paper is divided into sections that address:

- The current state of fire-danger rating R&D.
- The need for fire-danger ratings.
- Understanding the character of fire danger.
- The fire-danger rating system of 2007.
- The practice of rating fire danger in.
- Communication and display of ratings.

CURRENT STATE OF FIRE-DANGER RATING R&D

No work has been done on the NFDRS since the research project at Missoula was disbanded in 1978. Forest Service researchers at East Lansing Michigan, however, have completed a number of validation studies (Haines and others 1983, 1985; Main and Haines 1983). At the Forest Services's Intermountain Fire Sciences Laboratory, Andrews (1987) is developing a technique for matching fire-danger ratings with different measures of fire business.

NFDRS users meetings were held in 1985 at Salt Lake City, Utah, and in 1986 at Harper's Ferry. Virginia, to assess the need for additional research (and development). An outgrowth of those meetings is the impending transfer of R.E. Burgan from Missoula to Macon, Georgia. His assignment is to resolve NFDRS shortcomings identified by eastern users.

A 4-year contract for AFFIRMS has recently been awarded to the General Electric Company. (AFFIRMS was developed on GE and GE provided the service until 1980.) A multiyear program to develop a replacement system for AFFIRMS will begin later this year. That system will be called the Weather Information Management System (WIMS).

Dick Rothermel and his staff at the Intermountain Fire Sciences Laboratory are planning a program of research to develop the second-generation mathematical fire model. His project has also been given an assignment to develop an integrated fire management system inclusive of needs ranging from fire-behavior prediction to fire planning (Rothermel and Andrews 1987).

Dr. Mike Fosberg is embarking on a 5-year program at the Riverside Fire Laboratory to develop medium and long range weather forecasts for fire management (Fosberg and Fujioka 1987).

And we are here talking about fire-danger rating ......

THE NEED FOR FIRE-DANGER RATINGS

The need for a fire-danger rating system will not become less during the next two decades. The range of fire management tasks is expanding and those tasks require greater understanding and skill; they are increasingly complex (measured suppression response, fire effects); and the consequences of making poor decisions are more costly and politically sensitive.

The time horizon for projecting fire-danger ratings will certainly be pushed beyond the current 24 to 30 hours, a lead time sufficient for making decisions that affect local and subregional presuppression activities. The need to share increasingly expensive and scarce suppression resources among widely separated cooperators, however, has caused managers to ask for weather and fire-danger forecasts well beyond a couple of days.

The need for 15- and 30-day fire-danger projections has been documented. Thirty days is a goal for submission of emergency funding requests to the Congress and some state legislatures. The Washington Office of the Forest Service requires Forest Service Regions to give 2 weeks notice of a requirement for supplemental presuppression funding. Since May 1985, the National Interagency Fire Coordination Center (Boise, Idaho) has issued an "experimental" regional-scale, 30-day projection of wildfire activity (U.S. Department of Agriculture, Forest Service 1986).

By the mid 1990's the formats of both short and extended range fire-danger predictions will include estimates of uncertainty. The uncertainty resulting from the stochastic nature of the environmental drivers of fire danger, as well as the uncertainty inherent in the forecasting process, will be quantified. The current practice of making single value, deterministic predictions are not providing users with a complete picture of the actual fire-danger situation.

Though it will not happen in the near future, fire managers will develop and employ structured decisionDmaking [sic] systems based in the management sciences, including decision theory. Only then will management be able to properly consider the natural variability and stochastic character of fire danger.

UNDERSTANDING THE CHARACTER OF FIRE DANGER

Improvements to the performance and use of the NFDRS during the next several years will be modest. One reason is our poor understanding of the temporal and spatial scales of fire-danger. Getting more to the point, we don't know what scales of fire danger are possible to characterize and/or predict.

For instance, it is impossible to characterize, with a single rating, the fire danger near the ocean where there is a twice-per-day passage of a sea-breeze front. In such situations, the extreme diurnal variability of burning conditions require an approach more akin to that of predicting fire behavior.

Another shortcoming is our poor understanding of the temporal components of regional fire danger. Once those components are identified each can be tracked and integrated into a set of meaningful and useful ratings.

The components of a regions's fire danger are the result of the interactions of a region's fuels and weather cycles--diurnal, synoptic, seasonal, and climatic. Here is an example:

The spring fire season in the Lake States is nearly as predictable as spring itself. Its severity does vary, but there are few surprises. The typical spring fire burns in cured grass and reed-like plant debris, hence the key fuels are predominantly in the 1-hour and 10-hour timelag classes. The spring fire danger is determined by the highly transient weather elements, wind and relative humidity.

On the other hand, severe fire seasons such as 1976 are anything but routine. They are typically preceded by one to several years of below normal precipitation resulting in low water tables and exposure of normally saturated organic soils to the atmosphere. The 1976-class of fire season poses a completely different fire-danger rating problem than does the spring fire season. Its cause is a subclimatic shift of precipitation-producing weather events, and organic soils lie at opposite end of the fuel moisture response spectrum from dead grass. It is not possible for any single fire-danger index to do a good job in both of these situations.

FUTURE FIRE-DANGER RATING SYSTEM

The fire-danger system of 2007 will be complicated. Fire danger is a complex, multi-dimensional concept; its physical character varies tremendously across the range of conditions for which ratings are needed. I am confident that the fire-danger rating system of 2007 will look a great deal like the 1978 NFDRS.

The NFDRS offers the user a choice of six indexes and components. That number could certainly be reduced to four: ignition, fuel energy, burning, and occurrence.

Fire problems and the needs of the responsible agencies vary so greatly that a range of options must be provided. The menu of choices must include options that index the factors that affect ignitability, fireline intensity, composite fuel moisture (fuel energy), and occurrence.

The fire-danger rating system of 2007 will not be integrated with the fire-behavior and fire-planning systems to the degree that it will lose its identity.

<u>Fuels</u>

The Rothermel fire spread model (Rothermel 1972, Albini 1976) provided the basis for the NFDRS, the Forest Service's National Fire Management and Analysis System (NFMAS) (U.S. Department of Agriculture, Forest Service 1985), and the Fire-Behavior Prediction System (FBPS) (Rothermel 1983).

The spread model was modified to meet the special requirements of NFDRS and NFMAS. Though the modifications were minor, a unique sets of stylized fuel models had to be developed for each processor. This has, unfortunately, confused many users of the three systems.

The standard fire-danger rating fuel models will be a subset of the fuel models used for fire-behavior predictions and fire planning. The most significant change will be the licensing of users to develop their own fire-danger rating fuel models much as they can now do for the fire-behavior prediction system (Burgan 1984).

The fire-danger rating system of the future will account for the variation in fuel moisture responses to weather and plant life processes. Consider the Lakes States example in the preceding section and picture the tundra of Canada and Alaska. Contrast the character of those fuels with a common Great Basin fuel--a pure stand of annual grasses and forbs.

At least one additional fuel class will be added to represent organic soils, tundra, and deep duff and litter. The moisture-response model for this fuel class will account for transpiration as well as evaporation. Drawdown from transpiration may continue long after organic soil moisture reaches equilibrium with the atmosphere.

Live-fuel moisture models will certainly be improved as will dead-fuel moisture models (Rothermel and others 1986). More importantly for some areas of the country, will be a better understanding and modeling of the effects of living plants on fire danger.

A drought index will not be needed if satisfactory moisture models for organic soils and live fuels are developed.

Fire Danger for Extended Periods (2 to 30 Days)

What I have discussed, thus far, has been fire-danger rating in the traditional time realm--out to 30 hours. In this section the stickier issue of rating fire danger out to 30 days is addressed.

The capability to produce useful 6 to 10 day fire-danger rating products will lag behind yet-to-be-realized advances in extended range weather forecasting. No breakthroughs are expected for the next 20 years (Harnack 1986), but there is every reason to expect significant progress in the 2 to 6 day range by the mid to late 1990's.

More to the point of this paper, within 10 years it will be feasible to calculate daily, worst-case fire-danger ratings out to 6 days. I'm talking here about ratings that account for wind, the most elusive and challenging weather element to predict. The National Weather Service is now running its most sophisticated predictive models out to 10 days. They are showing great promise.

Beyond 6 days, an entirely different approach and fire-danger rating format will be needed. The reasons are: (a) the list of predicted weather parameters will not include relative humidity and wind, and (b) the predictions will be expressed as "departures from normal." Weather information of this type is adaptable for fire-danger rating purposes, but it will be usable only if there is a good historical record of fire-danger ratings from which "normal fire danger" can be determined. The required data has been collected and archived since the early 1970's (Furman and Brink 1975, Main and others 1982).

Integration With Fire-Behavior and Fire-Planning Systems

Dick Rothermel is looking ahead to a second-generation fire model that will account for the effects of large fuels on fire behavior and, possibly, model the behavior of fires burning in organic soils. That model (or family of models) should satisfy the specific requirements of all the NFDRS, NFMAS, and FBPS. That will make it much easier than now for users to change from one system to another.

The data demands of the second-generation fire model(s) will make them unsuitable for direct application in the fire-danger rating "beyond 6 days" time frame discussed in the previous section. I foresee a technological discontinuity at that transition point that will likely persist well beyond 2007.

THE PRACTICE OF RATING FIRE DANGER

GOES and remote automatic weather stations are changing the way fire-weather data is being collected. Since 1978, several hundred stations have been deployed by state and federal agencies, and more are planned. Almost all are now located in the far West and Alaska, but they will be common in the East before 2007.

Before the next 20 years has passed, fire weather will be collected from specially designed networks of automatic and manual stations. The numbers and locations of stations making up those networks will be determined by requirements passed down by management. Management will have finally determined how good the "answers" must be.

Some users will locate stations in the "woods," a practice commonly followed by our

Canadian colleagues. This will be an improvement for some. The "worst case" standard for taking the basic weather observation will be continued. More attention will, however, be given to the time the "worst" conditions actually occur.

More use will be made of weather data taken at non-wildland sites such as airports. Factors will have been developed to convert a 1- and 3-minute, 10-meter windspeed to an equivalent 10-minute, 20-foot windspeed. Neither will there be a need to weigh fuel sticks.

COMMUNICATION AND DISPLAY OF FIRE-DANGER RATINGS

Automated fire-weather stations will replace more than half of the manual stations by 1997. The replacement system for AFFIRMS will be in place by 1992. That will just about do it for the first half of the 20-year outlook.

No one knows what WIMS will look like; that will, however, be known before the year is out. Because of a consulting agreement with a private company I will not discuss my vision of WIMS, except that it will very likely make good use of micro-computers and will have limited "expert system" capabilities.

During the second half of the 20-year outlook, local data bases will allow each fire management unit to do its own planning, calculate and interpret its own fire danger, and make detailed fire behavior predictions for large, multiperiod fires. Uncertainty of both fire-danger and fire-behavior predictions will be quantified and that information incorporated in sophisticated computer-generated decision aids.

By 2007, the moisture contents of tundra, organic soils, and the full range of vegetation will be monitored from satellites and those data sent directly to the primary users. High resolution precipitation data from the weather radar network will be automatically integrated, along with the satellite moisture data, into operational fire-danger rating and fire-behavior prediction systems.

SUMMARY

--The need for fire-danger ratings will not disappear.
--Only modest technical improvements will be made to the NFDRS during the next 10 years.
--The 2007 NFDRS will look much like the 1978 NFDRS.
--A better understanding of the character of each region's fire danger will be the key to improved fire-danger rating system usage.
--Detailed, 6-day projections and regional trends of fire-danger ratings will be feasible by the mid 1990's.
--The format of predicted fire danger, beginning in the late 1990's, will include ranges of uncertainty.
--Fire-behavior, fire-danger rating, and fire-planning systems will be closely integrated, but not fully integrated.
--Satellite observations of vegetation and soil moisture conditions will be integrated into the fire-danger rating process.
--Weather radar will be the source of high resolution precipitation data for rating fire danger.

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REFERENCES

Albini, Frank A. 1976. Estimating wildfire behavior and effects. Gen. Tech. Rep. INTD30. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 92 p.

Andrews, Patricia L. 1987. The National Fire-Danger Rating System as an indicator of fire business. In: Proceedings of the Ninth Conference on Fire and Forest Meteorology. 1987 April 21-24; San Diego, CA. Boston, MA: American Meteorological Society; in press.

Burgan, Robert E.; Rothermel, Richard C. 1984. BEHAVE: fire behavior prediction and fuel modeling system D FUEL subsystem. Gen. Tech. Rep. INTD167. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 126 p.

Bradshaw, Larry S.; Deeming, John E.; Burgan, Robert E.; Cohen, Jack D., compilers. 1984. The National Fire-Danger Rating System: technical documentation. Gen. Tech. Rep. INT-169. Ogden, UT: Intermountain Forest and Range Experiment

Station, Forest Service, U.S. Department of Agriculture; 44 p.
Deeming, John E.; Lancaster, James, W.; Fosberg, Michael A.; Furman, R. William; Schroeder, Mark J. 1972, Revised 1974. The National Fire-Danger Rating System. Res. Pap. RMD84. Ft. Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 165 p.
Deeming, John E.; Burgan, Robert E.; Cohen, Jack D. The National Fire-Danger Rating System. 1978. 1977. Gen. Tech. Rep. INTD39. Ogden, UT: Intermountain Forest and Range Experiment Station. Forest Service. U.S. Department of Agriculture; 63 p.
Deeming, John E. Reflections on the development, application, and future of the National Fire-Danger Rating System. 1983. In: Proceedings of the Seventh Conference on Fire and Forest Meteorology. 1983 April 25-29; Ft. Collins. CO. Boston. MA: American Meteorological Society; 139-146.
Fosberg, Michael A.; Fujioka, Francis. 1987. Medium-and extended-range weather forecasting in fire management. In: Proceedings of the Ninth Conference on Fire and Forest Meteorology. 1987 April 21-24; San Diego, CA. Boston, MA: American Meteorological Society; in press.
Furman. R. William; Brink, Glen E. 1975. The National Fire Weather Library: what it is and how to use it. Gen. Tech. Rep. RM-19. Ft. Collins, CO: Rocky Mountain Forest and Range Experiment Station. Forest Service. U.S. Department of Agriculture; 8 p.
Haines, Donald A.; Johnson, Von J.; Main, William A. 1976. An assessment of three measures of long term moisture deficiency before critical fire periods. Res. Pap. NC-131. St. Paul MN: North Central Forest Experiment Station, Forest Service, U.S. Department of Agriculture; 13 p.
Haines, Donald, A.; Main, William A.; Frost, Jack S.; Simard. Albert, J. 1983. Fire-danger ratings and wildfire occurrence in the Northeastern United States. Forest Sci. 29(4) 19-26.
Haines, Donald A.; Main, William A.; Simard, Albert J. 1985. Operational validation of the National Fire-Danger Rating System in the Northeast. In: Proceedings of the Eighth Conference on Fire and Forest Meteorology; 1985 April 29-May 2; Detroit, MI. Boston, MA: American Meteorological Society; 169-177
Harnack, Robert P. 1986. Principles and methods of extended period forecasting in the United States, 1986. Meteorological Monograph ISSN-0271-1044. Temple Hills, MD: National Weather Association; 36 p.
Helfman, Roberts S.; Furman, R. William; Deeming, John E. 1975. AFFIRMS: Automated forest fire information management and retrieval system. Gen. Tech. Rep. RMD15. Ft. Collins. CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 136 p.
Helfman, Roberts S.; Straub, Robert J.; Deeming, John E. 1978. Users Guide to AFFIRMS: Time-share computerized processing for fire-danger rating. Gen. Tech. Report INT-82. Ogden UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 150 p.
Main, William A.; Straub, Robert J.; Paananen, Donna M. 1982. FIREFAMILY: Fire planning with historical weather data. Gen. Tech. Rep. NCD73. St. Paul MN: North Central Forest Experiment Station, Forest Service. U.S. Department of Agriculture; 31 p.
Main, William A.; Haines, Donald A. 1983. Determining appropriate fuel models from field observations and a fire characteristics chart. In: Proceedings of the Seventh Conference on Fire and Forest Meteorology; 1983 April 25-29; Ft. Collins, CO. Boston, MA: American Meteorological Society; 47-52.
Rothermel, Richard C. 1972. A mathematical model for predicting fire spread in wildland fuels. Res. Pap. INT-115. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 40 p.
Rothermel, Richard C. 1983. How to predict the spread and intensity of forest and range fires. Gen. Tech. Rep. INT-143. Ogden. UT: Intermountain Forest and Range Experiment Station, Forest Service. U.S. Department of Agriculture; 161 p.
Rothermel, Richard C.; Andrews, Patricia L. 1987. Fire behavior system for the full range of fire management needs. [These proceedings].
Rothermel, Richard C.; Wilson, Ralph A.; Morris. Glenn A.; Sackett, Stephen S. 1986. Modeling moisture content of fine dead wildland fuels: input to the BEHAVE fire behavior prediction system. Res. Pap. INT-359. Ogden, UT: Intermountain Forest and Range and Experiment Station, Forest Service, U.S. Department of Agriculture; 61 p.

U.S. Department of Agriculture, Forest Service. 1986. Short-term wildfire situation projection . Unpublished report. Boise, ID: Intelligence Section. National Interagency Fire Coordination Center: 5 p.

U.S. Department of Agriculture, Forest Service. 1985. Forest Service Hndbk. 5109.19, Fire Management analysis and planning handbook. Washington, DC.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Managing Research for Success[1]

Richard C. Rothermel[2]

Abstract: Maintaining a proper balance between fundamental and applied research is only one of the important considerations that must be adhered to in the management of Forest Service research. A critical mass of scientists with the necessary professional and technical staff is needed over the long haul for difficult research problems. The project leader must know how he or she intends to reach the user with research products. A conceptual flow of information from problem delineation through basic research to development of models and systems and, finally, testing and transfer to operational units has been shown to be an effective means of getting research into application. Each member of the work unit must understand the role they are playing at any time during the process. Finally, the scientists and project leader must be constantly aware of the hidden manager--the research grade evaluation panel, and make certain that scientists do not become isolated in developmental and applications work without sufficient publications to maintain grade.

Forest Service research is under continuous scrutiny, not only by research managers, but also by all Federal, State, and private agencies that have a vested interest in such research. Research organizations must therefore be particularly concerned about how the actual work units or projects where the research is done are organized and managed. By its very nature, research is difficult to manage. We in Forest Service Research are investigating problems that defy efficient resolution by available techniques. Understandably, such problems often require long and hard study for resolution. Because we are under the scrutiny of such a broad spectrum of both clients and managers, an equally broad spectrum of results is expected. Some want in-depth basic research; others, products that can be "applied in the field."

Individual scientists can survive very nicely by concentrating on-fundamental research. Our grading system has traditionally worked well for scientists doing basic research. Research work units, however, are rated over a much wider range of accomplishment. In simple terms, it often comes down to: "What have they done for us lately?" Therein lies the challenge to the project leader. I am not advocating change in our way of evaluating scientists or work units. I propose that our time is better spent learning to manage research programs that require a sustained effort over a long enough period to be truly effective.

We in Forest Service Research must be prepared to do not only research in the classical sense, but also development, testing, and application. It is imperative that we have in mind the form of the product that will be useful to land managers and organize ourselves to ultimately produce that product. Occasionally, the final product will be new hardware, which we have only a limited capability to produce. Fortunately, most products of our research take the form of either information or an information processor. Our capability to package and distribute information and disperse computer software is excellent.

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Fire research units may be more fortunate than the biologically oriented units because fire is a physical process that is easier to model deterministically. Moreover, many applications, such as long-range planning, prefire planning, and dispatching are well suited to the use of models and information systems that can readily be communicated and implemented through today's computer technology.

By structuring our research work units and our management of those units around this technology, we can not only become effective research managers. but also provide useful results to our clients. This emphasis on modeling and computer technology, of course, calls for strong efforts in both fundamental research and systems development, which, although difficult to maintain, have a synergism that strengthens both.

INFORMATION FLOW

The tasks required for this type of research are reflected in the flow of information within a work unit. The information flow that has worked well for our fire behavior unit at the Intermountain Fire Sciences Laboratory is shown in figure 1. The stages of the process, moving from left to right are:

1. Problem definition
2. Fundamental research
3. Model development
4. System development and packaging
5. Verification and demonstration
6. Handoff and application

Some research units have been successful without going through all of these phases, but the expectations for today's research require that they be considered when the course of a research program is planned.

The first stage, problem definition, must of course be conducted in concert with user groups and managers, including research managers. Problems must be selected very carefully. Priorities must often be set according to what can be done in a reasonable time. The final form of the product should be considered at an early stage. Our clients are often better served with fully developed research products, such as graphic displays or maps of fire-danger levels, rather than traditional publications and tables of numbers.

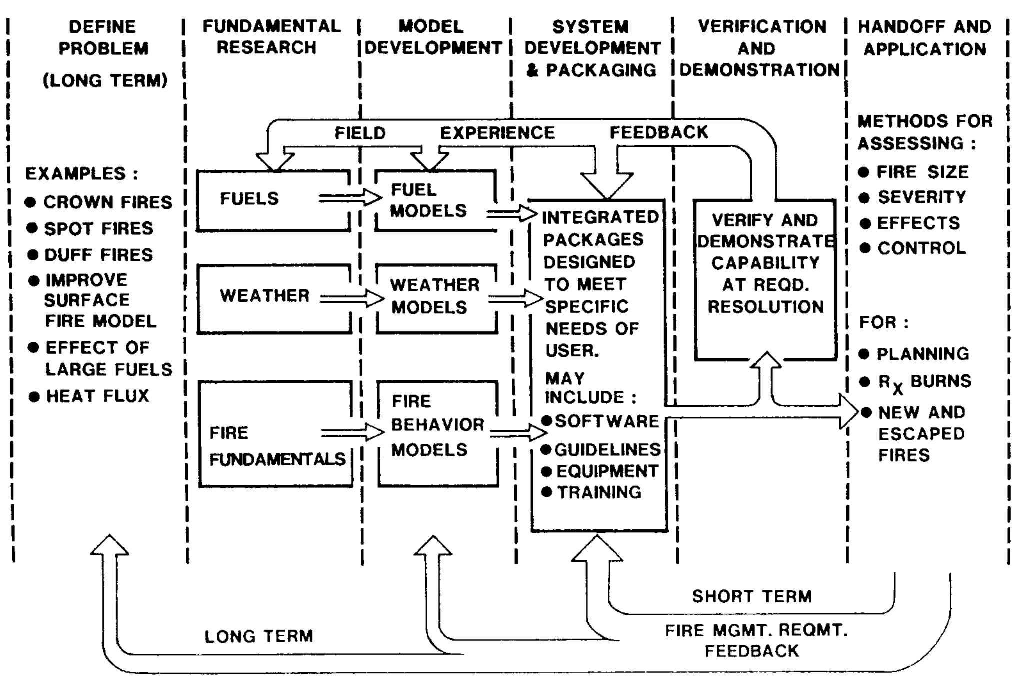

Figure 1--Successful information flow for the fire behavior research unit at the Forest Service's Intermountain Fire Sciences Laboratory, Missoula, Montana.

Problems are usually defined in client's terms, suggesting that only applied research will do the job, but basic research is often necessary before the applied work can begin. The research scientist's problem is usually very different from the client's problem. For example, the client's problem may be "How to predict the fuel moisture of fine dead fuels." The research scientist's problem is to identify the environmental factors that control fuel moisture, understand the processes involved, and develop a model that properly integrates all the variables according to season, time of day, and so on. Packaging the answer in a form the client can readily apply to the original problem lies near the end of the process.

The arrows at the bottom of figure 1 indicate the feedback necessary for problem definition, modeling, and system development.

The second stage, fundamental research, is a critical area that cannot withstand a great deal of introspection or directed management.

> "Research must be unfettered to be productive. Development must be controlled or it will never be productive."
>
> Myron Tribus

One of the primary qualities sought in a project leader is the capacity to provide research leadership.

By its nature, fundamental research can be exasperatingly slow. First attempts often fail. To capitalize on what was learned during initial attempts and proceed to successful discoveries, scientists must often continue their studies beyond traditional planning periods of 5 years or so. Our fundamental research on mechanisms of fire spread, at the lab in Missoula. for example, has continued for 26 years.

Conversely, some work units or "programs" have worked strictly on development and application without conducting any fundamental research whatever. They use results from other units and gleaned from the literature. Unless part of the research unit works at the fundamental level, such units cannot expect to outlive the system development and packaging phase. Research units are sometimes established as term projects with a specific expected lifetime. The National Fire Danger Rating Project, established for 3 years between 1975 and 1978, is an example.

The third stage, model development, is probably the least understood. Modeling can be thought of as a way of making research results usable and applicable over as wide a range as possible. Mathematical models are readily adaptable into today's computer technology. The more fundamental the research base for a model, the wider its applicability. Hence the importance placed on fundamental research and models based on first principles such as the conservation of energy, rather than correlations to locally measured variables. The best models give the most output for the least input. Models can be used independently or in conjunction with others. For instance, the fine-fuel-moisture model can be used directly or as an input to the rate-of-spread model. If properly planned and constructed, models can be linked so that a series of models functions as a system to meet a specific management problems (fig. 2).

The fourth stage, systems development and packaging, requires the services of people who are truly dedicated to producing a useful product. They must have a keen insight into the manager's needs and know how land management agencies operate. Management personnel are often brought into the systems development process. Current systems such as BEHAVE are strictly computer-dependent, thus adding another requirement to the talents needed by a good systems developer. Most of their work is hidden within a computer as an elaborate software package. The client sees "user-friendly" input and output statements and that's about it.

Systems developers fare very poorly in research-grade evaluation panels. This seriously discourages scientists from becoming involved in systems development. There are ways, however, of overcoming this problem. One method is to staff the systems section with personnel such as mathematicians, operations research analysts, or statistician/programmers who are not covered by the research-grade evaluation guide. Such a staff, however, may have trouble understanding the clients' problems or even communicating with the clients.

Happily, I have found strong exceptions to that fear. Another method is to temporarily use scientists normally engaged in basic research within the same unit. They move from basic research, to modeling, to systems development as needed. Such rotations, lasting a few months to a year or more, can be very productive for the unit and stimulating to the individual. For example, we used the talents of a research

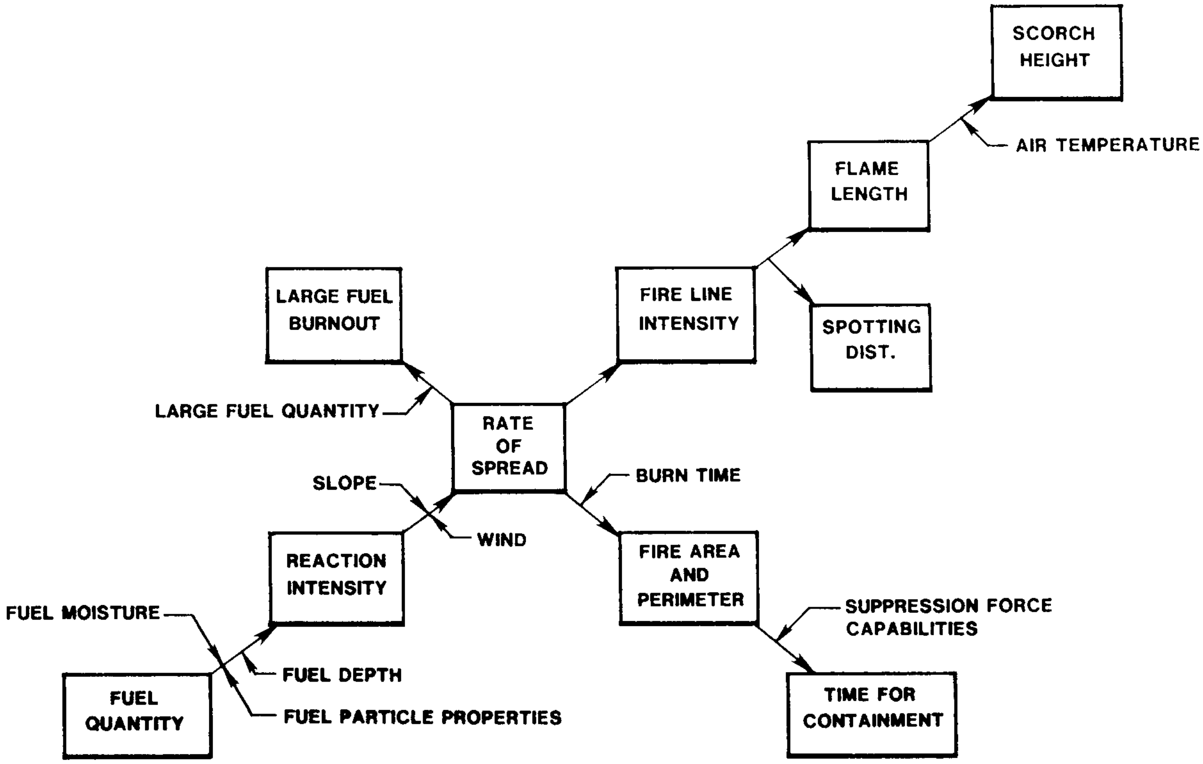

Figure 2--A series of fire models can be linked to meet a specific management problem.

chemist to help develop the computer programs for the HP-71B fire behavior calculator (Susott and Burgan 1986). During the process, about 1 year, the scientist learned a great deal about applying research in the field and the unit benefited by his programming skills and fresh approach.

"A change is as good as a vacation."
Anonymous scientist.

The fifth stage, verification and demonstration is often neglected. It determines how well the modelers and system developers succeeded. The feedback functions shown in figure 1 emphasize the importance of this phase. Testing should determine if the system can be used by others and whether it truly helps them or just adds to their problems. Both users and researchers should be involved in this stage. Often there should be two series of tests: a development test that is closely monitored by research and a pilot test with a fresh set of clients to learn whether the system and its documentation can stand alone. Systems should not be released for pilot testing to individuals untrained in the operation of the system.

The type of testing depends on the system and what it is intended to do. We are not looking for a lot of hard data for regression analysis on prediction capabilities. That should have been done during the modeling stage. Systems developers' time should not be wasted on models that have not been tested. Similarly, systems people should not extend models far beyond their intended use nor should they violate the assumptions under which models were developed. Clients must understand the assumptions behind the system and also its limitations.

The verification testing should reveal how well the programs function in an operational environment, how readily the user can supply the inputs, and whether the outputs are useful to the client. The usefulness of a system is readily apparent by the demand for its implementation by those involved in operational testing.

The sixth stage, handoff and application could be called technology transfer, but that broad term needs to be qualified. Forest Service scientists cannot serve as "county extension agents." There are too few of us for the number of clients. We have overcome that problem by training trainers. Through several consecutive years of instruction in the S-590 Fire Behavior Analyst course at Marana, Arizona, we developed a cadre of fire behavior analysts who were ready receptors for the programs developed for the TI-59 handheld calculator, BEHAVE, and more recently, the HP-71B calculator.

The BEHAVE system development (Andrews 1986, Burgan and Rothermel 1984) provides an excellent example of the concept of training trainers. Users were brought from all Forest Service regions and from other interested agencies to a series of 3-day, hands-on-the-terminal courses at the Intermountain Fire Sciences Laboratory in Missoula. Complete instruction packages were provided to every student. We conducted additional training at training centers in Portland, Oregon; Lone, California; and Anchorage, Alaska. A cascading process, from trainer to trainer, has distributed the system throughout the participating agencies.

An even more extensive travel itinerary was conducted for the TI-59 handheld calculator in 1979 when we conducted training in six cities. It was much easier to implement the HP-71B calculator in 1985. The technology was so well established that after program preparation and chip production, research played only a minor role in training. Detailers from NFS developed the training packages and conducted the training, starting with an agency-wide course in Marana. We have found this stage, especially the training, to be immensely rewarding to us in terms of feedback from users. Some of the students in our early classes have become important participants, and they provide excellent critical review of our proposed plans and system.

WORK UNIT GUIDES

The process I have described requires an adequate staff, facilities, and support. Small units of two or three scientists would be hard pressed to carry out a complete research-to-applications program. A critical mass of people, including scientists, professional support, technicians, and clerical help is required. Based on my experience, I advise against putting all the fundamental research in one unit and the applications work in another. Doing so eliminates flexibility and makes it difficult to obtain special help from a fundamental scientist from time to time. It also makes it difficult for scientists doing application work to move easily back into more fundamental work without rewriting work unit descriptions, transferring money, and instigating the associated personnel actions.

The working group should include a mixture of disciplines whose interactions will enable them to see the problem more broadly and sharply than working in isolation.

Before embarking on a program within this structure, the working unit must define the final form of their product. They must know how they will reach the user--even if application is several years away.

We have been fortunate in the fire behavior work unit to have had sufficient staff to operate in this mode since the middle seventies. It has worked well as evidenced by the influence the work of the unit has had on the fire science and fire management communities. At peak staffing, the fire behavior work unit was composed of:

1 research physical scientist
1 research engineer
3 research physicists
1 research chemist
1 research meteorologist
1 research forester
3 mathematicians
3 technicians
2 clerks

We were organized into two teams: (1) Fire Fundamentals, and (2) Fire Modeling and Systems Development. This was primarily for administrative purposes; we did not try to sharply divide the research. The number of personnel did not prove excessive for supporting the research in the large combustion facilities, wind tunnels, and other labs at IFSL. Surprisingly, the unit can operate effectively on a modest operating budget. Salaries obviously dominate the budget, but with good research facilities and adequate computer capability, operating funds are needed primarily to keep equipment up to date and to provide supplies. This picture is changing, however; we are losing and not replacing key personnel and we are faced with tough research questions that will take considerable time and money to answer. To cope with this situation, more money is going into cooperative agreements for outside research.

The modeling effort, described as stage 3, was not restricted to either team. Almost everyone did some modeling. Similarly, everyone at one time or another did computer programming. We do not think it is inefficient for scientists to program their own work. This is especially true when developing new mathematical models. When tested, proven, and ready for application, models are repackaged as necessary. Of course, routine data reduction, and so on, is better done by programmers and technicians, but we have been careful not to set up a computer czar to oversee all such work.

The work unit I have described evolved over a period of time by assimilation of scientists from disbanding units and key recruitments.

I am not so naive as to suggest that all research should be organized in this way, but I make the following recommendations for managing research for success:

1. Consider the steps shown, in figure 1 when any research unit is established.
2. Consider the form of the product the unit is expected to produce.
3. Allow ample freedom to scientists doing fundamental research.
4. Consider carefully whether your research can be packaged as mathematical models.
5. Carefully plan (control) the development work.
6. Keep the unit flexible so people feel free to occasionally move from fundamental to applied work, and vice versa.
7. Identify the problems of most concern to land managers in your discipline and seek their participation in devising solutions.

REFERENCES

Andrews, Patricia L. 1986. BEHAVE: Fire behavior prediction and fuel modeling system--BURN subsystem, Part 1. General Technical Report INT-194. Ogden, UT: Intermountain Research Station, Forest Service. U.S. Department of Agriculture; 130 p.

Burgan, Robert E.; Rothermel, Richard C. 1984. BEHAVE: Fire behavior prediction and fuel modeling system--FUEL subsystem. General Technical Report INT-167. Ogden, UT: Intermountain Research Station, Forest Service, U.S. Department of Agriculture; 126 p.

Susott, Ronald A.; Burgan, Robert E. 1986. Fire behavior computations with the Hewlett-Packard HP-71B calculator. General Technical Report INT-202. Ogden. UT: Intermountain Research Station, Forest Service, U.S. Department of Agriculture; 130 p.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Very Portable Remote Automatic Weather Stations[1]

John R. Warren[2]

Abstract: Remote Automatic Weather Stations (RAWS) were introduced to Forest Service and Bureau of Land Management field units in 1978 following development, test, and evaluation activities conducted jointly by the two agencies. The original configuration was designed for semi-permanent installation. Subsequently, a need for a more portable RAWS was expressed, and one was developed. The latest configuration is a truly portable, self-contained RAWS that can transmit via the GOES satellite or via the users' own radios. It contains a voice synthesizer and tells you what the weather conditions are at the station on your own radio. Possible future developments discussed include: Smaller, light versions; voice recognition circuits; data collection platforms that also transmit data.

The small weather stations used by the Forest Service and Bureau of Land Management (BLM) have traditionally been located outside ranger stations or similar offices. Once or twice a day someone dutifully treks to the station, observes and records instrument readings, and uses a telephone or radio to relay the data to some central or subcentral office. The data may then be entered, through a suitable terminal, into the Administrative Forest Fire Information Retrieval and Management System (AFFIRMS). AFFIRMS then calculates the localized fire danger rating, based on those and other data, in accordance with the National Fire-Danger Rating System (NFDRS) methods. Unfortunately, the weather at a ranger station is not always correlative with or even indicative of weather on top of a mountain, over the hills, or in other pertinent areas. Accessibility, cost of personnel and transportation, and time differences in readings have essentially precluded the use of nonautomatic stations for securing weather data in remote locations. Also, people are not always available, even at ranger stations, to read the instruments and report the weather data during fires or other abnormal situations--when they are most urgently needed. Those conditions led to the development and fielding of the first RAWS to see widespread use by the two agencies (Warren and Vance 1981).

BACKGROUND

It is often interesting and enlightening when looking toward the future to have a backward glance at where we were the same number of years in the past. In 1974, some remote weather stations and nets had been tried out, generally using a VHF radio link. Apparently all had limitations since they had not achieved wide-spread use. Basically, the VHF stations were limited to line-of-sight conditions, although that could be extended some by use of repeaters. This restricted their use to relatively small clusters of stations which could be interrogated from a ranger station or similar facility. That also required frequency allocations, repeater site availability, and people at a station to acquire and relay the data. The Geostationary Operational Environmental Satellite (GOES) was in orbit and just starting to be used by the U.S. Geological

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Survey and the U.S. Army Corps of Engineers to relay water level measurements from remote sites. By investigating, we found that the basic data acquisition and transmission package, called Data Collection Platform (DCP), could be adapted to other types of measurements and interfaced with weather instruments. We reviewed the DCP's with a commercial supplier, the entire GOES data collection and data processing systems operated by the National Oceanic and Atmospheric Administration-National Environmental Satellite Service (NOAA-NESS). and the frequency allocation arrangements. We concluded that RAWS using the GOES as a relay means was feasible.

In 1976, we obtained two DCP's on loan from NOAA-NESS, rounded up some instruments, built some interfacing circuits and cables, located a couple of used towers, and set up two operating RAMS working via the GOES. In 1977. Burea [sic] of Land Management procured two prototype RAWS from a commercial supplier, based on our two home-made stations. In 1978, following a meeting of Forest Service, BLM, and National Weather Service (NWS) meteorologists and engineers, the FS/BLM developed specs and procured five RAWS each which were installed and operated that year. Now, 10 years later there are some 400 RAWS operating in the field. The stations were designed as fire weather stations but are often used for other purposes on a year-round basis. In addition there are portable units available for temporary setup in various locations.

The RAWS now in use are microprocessor controlled, solar powered, use integrated circuits, have timing accuracies of seconds per year, contain solid state memory, transmit by satellite, operate unattended, and withstand a wide range of outdoor environments throughout the continental United States and Alaska. That was conceivable, but might have been considered a far-out projection 13 years ago.

PRESENT RAWS STATUS

Several configurations of RAMS are now available: the semi-permanent, transportable, and portable. Any of the types can be equipped to transmit via the GOES /or via the users' own radios in voice or data mode, or both. The GOES transmissions must be made at an assigned time on an assigned frequency. An emergency channel can be used which will activate a transmission if certain parameters are exceeded. This is often used for water level measurements via the GOES but has not been used for weather measurements to any great extent.

The radio transmissions occur when the user "interrogates" a station. Each calling transceiver must have a touch-tone type pad so the proper station can be selected. Up to nine RAWS could be accommodated on one frequency. The RAWS DCP's are programmable so that the proper transmission time can be selected and the various measurement parameters entered. A standard set of measurements with standard characteristics is usually used and a Programmable Read Only Memory (PROM) is available which greatly alleviates the programming task. The DCP's can also be completely programmed in a shop and then shipped and activated on arrival at the field site, so that a programming test set is not even required in the field.

FUTURE RAWS

The present RAMS configurations and methods now widely used had not even been conceived 13 years ago, so it may be a little hazardous to try some future projections, but here COES (pardon the pun). A much smaller, lighter weight RAWS is probably achievable now. The present very portable RAWS likely will be succeeded by one even more portable. Perhaps we could call it an ultraportable. A suitcase size or perhaps briefcase size system could probably be developed. The major obstacles would be the sensors and something to hold it in place in case of high winds. Batteries will tend to limit the reduction in weight, but again we need something heavy to hold it in place anyway. These ultraportables could be used as standard electronic/sensor packages and simply be attached to other tower structures where the twenty foot wind sensor height is needed by using extender cables.

Programming could be simplified by selecting a few standard configurations and simply using a single digit number and ENTER for programming. For self-timed stations on a preset schedule, there will always be a need for entering the transmission time, transmission interval, and the present time--coordinated to GMT.

Programming might also very well be accommodated without a special programming test set. Voice recognition circuits are advancing and we could likely include enough vocabulary in the DCP so that we could simply tell it what time we want it to transmit, how often, and even any special instructions. The DCP would recognize what we said, set itself up and then repeat back to us how it had programmed itself as a final check. There could also be some self-diagnostics included so if a unit has a malfunction it could tell us the probable cause (unless, of course, its voice box was the problem).

The DCP's could be designed to always transmit data rather than voice. That would speed up the transmission time and reduce frequency congestion. The interrogating transceiver would have a small integrated circuit memory which would store the data, and a voice synthesizer to tell you what the weather measurements are. The transceiver could also or optionally be connected to a data terminal for display, secondary storage, and processing of the data as well. Personal transceivers may include a data storage/display capability by 2000 anyway.

DCP's could calculate the fire danger rating for the area based on measured and stored data. They could also calculate the fuel moisture content. An algorithm has been developed which could be adapted to the RAWS (Deeming 1983). Based on results to date it doesn't seem too likely that anyone will develop a good reliable. accurate fuel moisture sensor with any reasonable mean time before failure (MTBF) in the next 13 years.

Whether by radio or satellite link, the weather from several ultraportables located strategically around the tire or from more permanent RAWS likely will be available at the ICP and presumably could be entered directly into the fire spread and prediction models which will be developed and in vogue by 2000 (Burgan and Shasby 1984. Rothermel 1983). The computers for the models could be located at the ICP or some other location--it won't matter, for as I've been saying for the last 10 years, it is absolutely certain that in 10 years we'll have full satellite communications (voice/data/video) available from ICP's to any other location.

Not necessarily a RAWS (but related to satellite communications) prediction: there will be small satellite terminals capable of receiving the GOES weather pictures either direct or relayed from another ground terminal with better resolution than is now available.

Other sensors could be added to RAWS such as visibility, particulate, and acid rain sensors. Motion or proximity sensors could be used if vandalism becomes a problem.

Advances in very large scale integrated circuits (VLSI), microprocessors, and digital signal processing should permit virtually any level of processing desired to be accomplished within the small portable RAWS or at some other convenient location. Availability of mobile/handheld satellite communications similar to the cellular radio (mobile telephone) services available in the larger urban areas now will permit access to any remotely located station about as simple as dialing a telephone number. The response could be in either voice or data.

Maintenance costs could be greatly reduced by providing a minimum amount of self-test circuitry which could be interrogated remotely and in most cases isolate the problem to the DCP, a sensor, or a cable. The needed part could be shipped to the field for replacement of the failed part without the need for field diagnosis by an experienced electronics technician. Reprogramming, if necessary, could be accomplished before a new DCP is shipped, or remotely.

In summary, the ultimate weather reporting system might enable us to know what the weather is doing now, what it has done in the past, and what it will do at any time in the near future at any location of our choice. Coupled with other inputs, the present and future fire location and activity could also be predicted to a high degree of accuracy.

REFERENCES

Burgan, Robert E.; Shasby, Mark B. 1984. Mapping Broad-Area Fire Potential from Digital Fuel, Terrain, and Weather Data. Journal of Forestry 82(4): April.

Deeming, John E. 1983. A Preliminary Model for Calculating the Ten-Hour Timelag Fuel Moisture from Hourly Weather Data. Proceedings, Seventh Conference Fire and Forest Meteorology.

Rothermel, Richard C. 1983. BEHAVE and You Can Predict Fire Behavior. Fire Management Notes 44(4).

Warren, John R.; Vance, Dale L. 1981. Remote Automatic Weather Station for Resource and Fire Management Agencies. Gen. Tech. Rep. INT-116.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

The Great Basin: Wildland Fire Management in the Year 2000[1]

James B. Webb[2]

ABSTRACT: The future of wildland fire management depends on the course chosen by fire managers today. Our responsiveness to issues will determine how much we influence where we go. Economics in concert with a better appreciation of fire's role in ecosystem dynamics will significantly alter fire management as we know it today. Public subsidies of homeowners who refuse to take prudent fire prevention actions will dwindle. Risk management will be clearly understood. We will no longer spend more then a property is worth to protect it. Our work force will change both internally and externally. There will be many opportunities for initiative, creativity, and ingenuity to blossom.

Assumptions are important when we look into the future. For you to understand my perspective, you must know what assumptions I carry into this presentation. My assumptions include:

--We determine the future by setting goals and objectives.

--The future is irrevocably keyed to our performance today.

--All change takes time.

--The next 14 years will pass like 7.

[1]Presented at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

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My comments are by no means meant to be irreverent. I have been an active, willing participant of the past. With this baggage unpacked, we will now build a vision of the future.

Cooperation between fire agencies will intensify. Driven by our own quest for efficiency and tight budgets, we will complete integrated fire management analysis. Duplication of forces will not exist.

No longer will you see engines driving past one another to get to fires. Areas will be designated for initial attack based on fastest response rather than agency jurisdiction.

Structural protection is the one issue that will complicate cooperation more than any other. I don't see the Forest Service changing its long-standing position to avoid entering structures.

Agencies with wildland and structural responsibilities will take the lead in urban/wildland interface areas.

Forces will be highly trained and motivated by professionalism. Much like today, we will be a highly energized workforce.

By the year 2000, we will be approaching racial and gender parity in the Great Basin fire community. Women and minorities will be well represented in all levels of most organizations. This will not come easily. A concerted effort will have actively recruited and nurtured people to succeed in a previously white-male-dominated profession.

Training and technology interchange will be spontaneous. Our desire to provide cutting edge services will overcome the provincial momentum we are so actively working to overcome.

Fire's role in ecosystem dynamics will be thoroughly understood. Management decisions will be based on this expanded awareness. The public will push us toward more responsible fire suppression. Left to our own devices, it will be difficult for us to objectively critique our actions.

Economics will be a paramount decision criterion well before 2000. We can ill afford to spend a million dollars to suppress a fire doing very little resource damage. Suppression costs and damages will be closely monitored. We will be held accountable for gross disparities.

Protection of property will be in perspective. People who choose to live in fire prone environments will have better guidance on prevention methods. They will also have the right to experience the consequences of their decisions. They'll no longer be subsidized by local governments or the American Insurance System. The "Wild Fire Strikes Home Initiative" will be recognized as one of the finest examples of public and private sector cooperation. Most of the issues will be resolved. Zoning and building codes will be established that significantly reduce the potential for structural loss during wildfire intrusions into developed areas.

Green belt management will be recognized as mutually beneficial by developers, fire agencies and private landowners.

The homeowner's responsibility will be clear. When these responsibilities aren't met, fire agencies will not be expected to compensate for the homeowners mistaken assumptions that someone will bail them out.

Satellite detection and monitoring of ignitions will be common-place. Computer aided decisionmaking and dispatch will be well established. Clear, accurate predictions of the emerging fire's impacts will trigger a wide variety of responses.

Real time audio-visual relays will be transmitted from incident sites to command and coordination centers. This information will facilitate communication and decisionmaking by a diversified group of managers.

Risk management will be well understood. A risk assessment will be a critical element of each prescribed fire and wildfire decision. Managers will be comfortable with strategies thought to be irresponsible today.

We will finally recognize the limited influence mortals have on Mother Nature when she unleashes her spirit. Utilizing significantly less forces, we will accomplish much the same thing we do today without spending the money. Suppression damage and scars will be minimized and our people exposed to less hazards.

Our ability to manage suppression forces will match our total mobility effectiveness. Incidents involving more than 1,000 people will be rare. We will understand where our energies can be effective and where the vagaries of nature will prevail.

The public will no longer equate aggressive fire suppression with large airtankers and a cast of thousands.

Aerial retardants and delivery systems will be radically different. Foams and yet unidentified substances will be placed with pinpoint accuracy by large helicopters and single engine aircraft.

Successful initial attack and first reinforcements will be provided with aerial ignition devices. Fire will be fought with fire again.

In many instances a small crew supported by aerial ignition equipment will handle fires normally relegated to large incident mangement [sic] teams. Our ability to determine inevitable final fire size will encourage us to get on with burnout to rational natural barriers.

Use of the confinement strategy outside wilderness will be socially and politically acceptable. No longer will we as fire managers calibrate our success based on minimum acres burned. Costs and damages will be our measure of success.

Contracting with the private sector for fire management services will be a growth industry. Public fire managers will be contract inspectors and specification writers.

The renaissance of fire effects awareness will trigger a quantum expansion of the prescribed fire program to 500,000 acres a year on National Forests in the Great Basin alone.

Range conservationists, wildlife biologists, and silviculturists will advocate using prescribed fire to enhance the vegetation they manage.

State game officials, ranchers, and the various preservation organizations will form an unusual coalition to encourage us to utilize fire to meet their goals.

After many skirmishes, the air quality issue will be resolved. Fire will replace pesticides and machines as the tool of choice in vegetation manipulation.

CONCLUSIONS

This may seem like a conservative manifesto. I urge you to consider our progress in implementing what, for the Forest Service, was an expansive revision of fire policy in 1978. The "10-acre/10 a.m." policy was replaced with latitude to adjust suppression activity to minimize the sum of fire-fighting costs plus damages. Today, 9 years later, we are on the threshold of embracing that concept. We are yet to understand the implications of such freedom.

We will in effect learn to peacefully coexist with one of the dynamic forces that shaped so much of what we value today.

Fire specialists will be sought after for their management skills and land ethic. The keys to achieving this future include:

Professionalism--Not being afraid to make mistakes when actions are based on "state-of-the-art" methods and sound application.

Outreach--Fire management practitioners need to see themselves as active participants in the social/political arena. We should expect scrutiny and relish the opportunity to interact with the public.

Strong Land Ethic--We must never lose sight of our foundation rooted in practices that begin with the question "What is best for the land?"

Forest Fire Advanced System Technology (FFAST): A Conceptual Design for Detection and Mapping[1]

J. David Nichols and John R. Warren[2]

Abstract: The Forest Fire Advanced System Technology (FFAST) project is developing a data system to provide near-real-time forest fire information to fire management at the fire Incident Command Post (ICP). The completed conceptual design defined an integrated forest fire detection and mapping system that is based upon technology available in the 1990's. System component technologies identified for an end-to-end system include airborne mounted thermal infrared (IR) linear array detectors, automatic onboard data georeferencing and signal processing, satellite communications links, and advanced data integration and display. The conceptual design detailed the preferred system configuration that warrants continued refinement and development for operational use in the 1990's. The FFAST design will be the baseline for the next generation of forest fire detection and mapping systems after the year 2000.

Thermal IR sensing for forest fire detection and mapping has been under development and use by the USDA Forest Service since the FIRESCAN Research Project began in 1962 (Hirsch 1968).

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Project FIRESCAN was a study to examine the use of airborne, IR line scanners for detecting latent forest fires and for mapping the perimeter of large fires. The original Forest Service airborne. IR, line-scanning systems were based upon research conducted during the FIRESCAN Project. The Forest Service has used fire mapping systems operationally since 1964 (Warren and Wilson 1981). The initial airborne systems were stand-alone IR systems designed to produce hard-copy images, onboard the aircraft, of thermal characteristics of the terrain and fire. Timely delivery of fire imagery to a fire camp was a problem as the imagery was delivered either via drop tube, conditions permitting, or hand delivered via ground transportation from the nearest airport.

The original scanner units became obsolete due to improvements in technology and the increasing difficulty in maintaining the units for operational readiness. Replacement parts for the scanner units were difficult to find and in some cases had to be custom built.

The Fire Logistics Airborne Mapping Equipment (FLAME) project, a joint effort between the Forest Service and the National Aeronautics and Space Administration's (NASA) Jet Propulsion Laboratory (JPL), was charged with designing, developing, and implementing a modern, airborne, IR detection system with improved performance and flexibility over the original systems (Enmark 1984). As a result of the FLAME project, the Forest Service's Texas Instruments RS-7 scanner was replaced with a hybrid system providing increased spatial resolution (instantaneous field of view of 1 milliradian), improved response time and data capture, and real-time video display and storage.

The Forest Service airborne sensor systems in use today are the only ones in the world designed specifically for fire detection and mapping. The systems are rotating-mirror, thermal IR line scanners that use dual-element detectors in the 3 to 5 and 8 to 12 micrometer bands. The field of view (cross track of 120 degrees) is rapidly swept across the flight line in a direction perpendicular to the aircraft's axis. The sensor systems are relatively large and heavy, require large amounts of power, and need liquid nitrogen for cooling. The physical delivery of fire data to the fire camp ICP normally requires 1 to 4 hours, followed by 1 to 2 hours of scaling and interpretation.

The inability to deliver timely IR fire information to fire management personnel has continued to be a serious problem. IR data collection, image data transmission, processing, storage, and display systems using the latest technological advances must be identified and evaluated to meet the critical challenges facing the Forest Service. A joint effort to examine this problem was initiated between JPL and the Forest Service in 1983.

OBJECTIVES

The objectives of the conceptual design study were to examine in detail user requirements for tactical information on forest fire activity, document functional requirements for a completed system, examine technology that will be available for application to the project objectives, and prepare a preferred system configuration. The results of the conceptual design will be applied to forest fire mapping and detection to be used by the Forest Service and cooperating agencies in the 1990's. To accomplish the objectives, uncertainties in emerging and advanced technologies related to the conceptual design were identified. Operational capabilities and characteristics as well as functional requirements were determined.

APPROACH

Analysis of component and subsystem technologies and function were performed, including value analysis,[3] tradeoff evaluation process[4] studies, and projection of technology availability. Areas of risk were identified and alternative approaches defined. This approach was followed to maintain the appropriate technology level for the system and to ensure that the most economic means of design and implementation are pursued.

There are five basic considerations behind the design philosophy of the FFAST system. The first consideration is that the new system will have improved timeliness over the current system. The new system will produce the end product within 30 minutes of actual data collection. The second consideration is the improved accuracy the system will have over the existing system. The third consideration is the modularity of the design to facilitate service, reliability, maintainability, possible upgrading, and long life. The fourth consideration is the ease with which the system can be used. Extensive operator training should not be required. A user manual should be necessary only during initial training and to remind the operator of the full capabilities of the system after a period of no usage. The fifth consideration is the use of commercially available components, when possible. Off-the-shelf components will decrease system development costs.

FUNCTIONAL REQUIREMENTS

To support the conceptual system design effort, a set of functional requirements for the FFAST system was developed (Dutzi 1984). Functional requirements were based upon the identified user needs compiled from meetings with Forest Service Regional Fire and Aviation Management Directors and their staffs, and technical judgement. The functional requirements identify the functions necessary to satisfy user needs for a fire detection and mapping system with improvements over the system used currently. The FFAST functional requirements fall into two categories:

1. Basic requirements:
   a. Accurate data acquisition.
   b. Timely georeferencing of fire data.

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[3]Methodology is from the USDA Forest Service Value Engineering Workshop. Washington, D.C., November 28 to December 1, 1983.

[4]Methodology is from the USDA Forest Service Tradeoff Evaluation Process Workshop, Boise, ID. October 10, 1984.

c. Timely delivery of thermal IR image data.
d. Improved voice and data communications.
e. Improved image processing capability.
f. Improved data reduction and display.
g. Compatibility with other systems.
h. Conventional map output products.
i. Reliable, rugged, and easily maintainable.

2. Desired attributes:
   a. Integration of distributed data bases.
   b. Modeling capability.
   c. Adaptable to other forest management areas.
   d. Easily integrated into Forest Service procedures.

The functional requirements provide a framework for the conceptual design effort. The baseline design description will use the functional requirements as a foundation from which to develop components that will fulfill the objectives of the FFAST project.

BASELINE DESIGN

The conceptual design of the FFAST system focused upon technology that will be available and sufficiently mature by the 1990's to aid users in fire detection and mapping. The baseline design supports the development of system components that will meet the functional requirements objectives.

Collection of Fire Data

Thermal IR sensing of forest fire perimeters and related hot spots is performed in the two prominent atmospheric transmission windows, 3 to 5 and 8 to 12 micron bands. Instruments operating in these two bands are able to detect fire and terrain features through smoke clouds.

Two thermal IR sensing methods can be useful in fulfilling the functional requirements for the collection of fire data. The current method in use is infrared line scanners that have single- or dual-element detectors. Line scanners work when the field of view is rapidly swept across the flight line in a direction perpendicular to the aircraft's axis. The system scanning mirror must move fast and must be rigidly supported to produce good images. Thus, line scanners tend to be massive and built on a custom-design basis. The second method is the use of linear array detectors configured to produce an image from the ground swath as the system is flown over the site of fire data collection. The linear array is oriented perpendicularly to the aircraft axis and each detector traces a separate line on the ground. The linear array detector design is commonly referred to as a pushbroom scanner because the detectors are being pushed across a scene as opposed to being swept from side to side as in the design of the line scanner.

Linear array, IR detector systems are currently available on a custom-design basis built to meet user requirements. The materials used are mercury-cadmium-telluride for the 3 to 5 micron range currently available, and either the same materials or gallium-arsenide, which are projected to be available by 1990, for the 8 to 12 micron range. Element dimensions vary with up to 128-element arrays presently being built. Larger arrays are projected for future production. The linear array lightweight and small size, about 50 kilograms (approximately 100 pounds) when combined with a storage device and microcomputer processor, make such system components ideal for use in aircraft platforms smaller than those presently used by the Forest Service for IR missions.

Fire Data Processing

Forest fire detection and mapping involves the comparison and contrasting of variables associated with fire behavior. The most important need is the ability to locate fire targets produced from the IR data collection system with respect to known geographic positions on the ground. Fire targets can be positioned if the IR image data is georeferenced to a standard cartographic base (map).

To georeference fire data, it is necessary first to know the position of the sensor platform (aircraft) and then the location of the scene imaged by the sensor system; this image data is then correlated with the cartographic base. The standard georeference correlation procedure identifies common points between the IR image data and the map, then uses the common points to overlay the image data on the map.

A number of technology items were identified in the design technology assessment as possible candidates for determining the location of the sensor platform for georeferencing. Alternatives included LORAN-C, Geostar, Inertial Navigation System, OMEGA, TRANSIT, and the NAVSTAR Global Positioning System (GPS).

The GPS is being developed to provide highly precise position, velocity, and time information to users, 24 hours a day, worldwide. The navigation position accuracy will exceed the requirements of FFAST. GPS hardware and software are available commercially.

Communications

The communication component is the single weakest link in the existing system. The inability to deliver the data reliably in a short period of time (less than 30 minutes) has hampered incorporation of fire data in the daily fire suppression plan. Land lines in remote locations are not readily available and VHF/UHF communications are limited to line of sight or repeater networks. The most promising method of communication appears to be via satellite link.

Remote mobile land and aeronautical communications via satellite will provide service comparable to current urban cellular telephone systems, but on a nationwide basis. Satellite communications are based on the positioning of a satellite in an equatorial, geostationary orbit at an altitude of 22,300 miles. Communication stations transmit and receive voice grade data via the satellite. Two or more stations work in a duplex mode (simultaneous transmission and reception) using the satellite as a relay.

Fire Data Display

The functional requirements dictate that the final output of the FFAST system be accepted and used by the fire control management at the ICP. Image data processing techniques and equipment are available to extract, enhance, reduce, and display fire data in a number of formats.

Historically, fire perimeter information is plotted on a standard map base, usually a standard United States Geological Survey (USGS) 7-1/2 minute quad map. Fire data plotted on a map base is the display product users require. The fire data that should be included in the end product will be the fire perimeter, fire hot spot, and fire intensity. The fire data, transmitted from the airborne platform via satellite voice/data grade links to the ground station, will be automatically scaled and plotted accurately. Ground station equipment, a small ruggedized personal computer and a pen plotter, have been demonstrated operationally by the Forest Service.

TECHNOLOGY ASSESSMENT FOR BASELINE DESIGN

The FFAST system baseline description prompted the assessment of technologies that could be considered potential system components. The technology assessment, detailed in Nichols and Warren (1986), was an analysis made to address the following items:

1. Sensor systems.
2. Global positioning technologies.
3. Georeferencing techniques.
4. Satellite communications.
5. Data bases and Data Base Management Systems (DBMS).
6. Data storage devices.
7. Data display devices.

The technology assessment of each of these items is in terms of its application to the FFAST system, and its projected availability as a result of continued technical evolution. Accordingly, the technology assessment implies that the FFAST system is modularized, and that the new technology items can be integrated into the system configuration as they become mature and commercially available. Because of likely availability, the emphasis of the technology assessment is on nonclassified technology. Only those commercially available items that have been technically proven will be considered for possible final system integration.

ALTERNATIVE FFAST SYSTEM CONFIGURATIONS

Alternative FFAST system configurations have been developed with regard for future Forest Service information needs. The alternatives are intended as baseline configurations. The preferred system configuration was formulated as a design on which a subsequent detailed design may be built. The alternative configurations and their associated technologies, detailed in Nichols and Warren (1986), aid in the refining of the total system design. An alternative FFAST system configuration matrix summarizing the alternatives is presented in table 1. The current Forest Service IR system is used to allow a point of comparison.

The candidate FFAST system configuration alternatives were evaluated for factors considered to be of paramount importance when comparing potential system configurations. The FFAST alternative configurations, with a delivery of fire data to the fire ICP in less than 30 minutes, have at least a 3-hour advantage over the present IR system. The FFAST system configuration option A alternative has the line scanner disadvantage of projected high maintenance, difficulty in calibration, large size, and weight. The option C alternative uses a single-band linear array, which is a technical uncertainty. The single-band linear array may not provide a fire detection capability that will meet the system functional requirements. The option D alternative would utilize a central ground facility to process the uncorrected IR data of fire perimeter and intensity. Option D would retransmit the fire data to the ICP. The transmission and retransmission of the data in option D and the use of the processing at a central ground facility would consume extra time, causing potential system inefficiencies.

Option B is the best FFAST system alternative configuration based on the results of the evaluation processes. The dual-band linear array component used in option B is the most promising alternative as verified by the fire data collection analysis procedure. Onboard data georeferencing is an important factor in producing the end product in a timely manner. Satellite communications allow option B to transmit data in near-real time without the concern for line-of-sight data transmission. The compact size of the option B system will allow the platform to be a smaller aircraft than presently used. The option B configuration has the least amount of technical uncertainty, the advantage of onboard data processing, and small size, while still meeting the functional requirements of an advanced forest fire detection and mapping system.

Table 1--Alternative FFAST system configuration matrix

Component	FFAST alternatives				Current system
	A	B	C	D	
Collect data					
Line Scanner	X				X
Linear Array 1 band			X		
Linear Array 2 bands		X		X	
Data processing					
Advanced georefer-encing	X	X	X	X	
Advanced registra-tion	X	X	X	X	
Automated on-board aircraft	X	X	X		
Registration and rectification at ground facility				X	X
Communication					
Satellite	X	X	X	X	
Data display					
Advanced display at ICP	X	X	X	X	
Platform-size class					
King air	X				X
Merlin	X				X
Baron		X	X	X	

PREFERRED SYSTEM CONFIGURATION DESCRIPTION

The FFAST preferred system configuration (option B alternative) is shown in figure 1. The thermal IR linear array will use two 1024-element linear arrays, one in the 3 to 5 micron band and the other in the 8 to 12 micron band. Dichroic beam-splitter optics will separate the energy input in the two bands and route them to the appropriate arrays. The

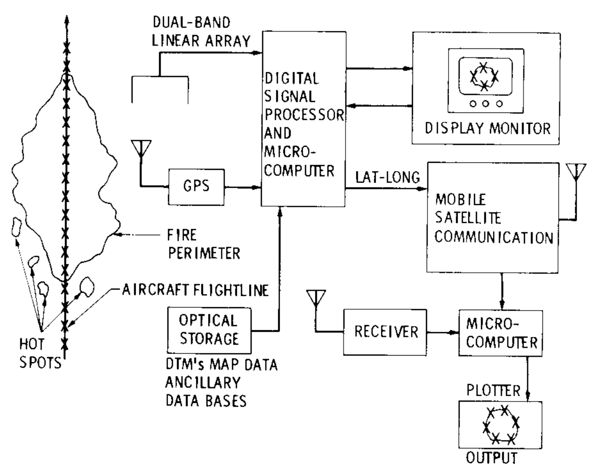

Figure 1--Preferred system configuration.

dual-band array-will retain the same detection capability achieved in the Forest Service's existing airborne IR line scanning systems yet it will be smaller, lighter, and more easily transportable to smaller aircraft. The output of each corresponding detector element in the two arrays will be synchronized, pixel by pixel. Hot spots must pass a predetermined signal criteria to be recognized as legitimate targets. The outputs of the two bands are subtracted in a scaled manner (kA-B), which leaves the target (hot-spot) signals outstanding. The signals are stored in a one-line buffer. The ground area is deliberately over-scanned so that every pixel area is viewed at least twice. The target must show up at the same pixel location in the next scanned line to be accepted as a real target. This eliminates random noise spikes from passing the target selection criteria and thus greatly reduces the false alarm rate. The 8 to 12 micron band is used for target verification and displaying terrain features to coordinate with maps, orthophotos, and other data stored onboard the aircraft. The 3 to 5 micron band will provide target information.

The thermal IR image data is correlated to ancillary data onboard the aircraft. Stored image features, such as roads, streams, ridges, and other known physical characteristics may be highlighted by the system. The IR image will be digitized and stored for display along with the previously stored images. When the images are overlayed on the video/graphics display monitor, identifiable features will be matched to remove any distortions in the IR image and to correlate with the map data.

The GPS receiver will provide precise information on the position of the airborne platform. The positional data will be stored onboard for display and computation. Maps and images stored on optical disks can be displayed on the graphics display monitor with the aircraft track superimposed. The location of the aircraft, stored terrain elevation features, and the IR image data can be positioned simultaneously and scaled on the display unit. When all pertinent characteristics are matched, fire perimeter and associated hot-spot fire target data will be highlighted to register automatically and store latitude and longitude points.

Upon completion of fire perimeter and other point storage, the data will be transmitted via a geosynchronous communications satellite link (voice grade, low data rate) and received at various locations including the ICP. The fire data will be stored in a field-durable, portable computer, and subsequently plotted on a USGS topographic map for use by the fire management team.

CONCLUSIONS AND FUTURE DEVELOPMENTS

The preferred system configuration will meet or exceed the user's functional requirements for an advanced forest fire detection and mapping system. The entire system will be transportable from one aircraft to another, thus precluding the need for a dedicated, large (twin-turboprop-size) aircraft. The modular design of the preferred system provides flexibility by allowing the incorporation of both present and developing technologies. The preferred system will make it possible to acquire and integrate the requisite information into a high-resolution, user-friendly system which will perform fire detection and mapping on a near-real-time basis. The system will also be adaptable to nonfire, multiple-user reconnaissance missions by incorporating the use of sensors other than those in the 3 to 5 and 8 to 12 micron bands.

The FFAST conceptual design was based upon sound engineering design practices utilizing technology either available today or reaching maturity in the near future. The FFAST operational system will be nearing the end of its design life in the year 2000.

The next generation fire and mapping system will be based upon technological advances that are foreseeable today and may occur in the next 13 years. Technological advances will be made in the areas of sensor development, optics, observational systems, and precise locational capabilities as direct spinoffs from development work for the U.S. Government's Strategic Defense Initiative and ongoing NASA space exploration activities. Remotely piloted vehicles may develop to the point of being able to carry extremely compact, ultrahigh-resolution sensor systems capable of sensing, processing, and transmitting tremendous amounts of data. Fire data could be coupled with multiple databases (such as topographic map. fuel moisture, rates of spread, fire behavior, resource values, economic impact models, fire effects models, weather data) integrated and displayed on a pocket-size video monitor for fire personnel in the field. High-resolution earth-observing geosynchronous satellite systems using sensors capable of seeing through clouds and smoke may be able to monitor constantly both high-fire-danger areas and ongoing wildland fires. Instanteous [sic] voice, video, data and data communications could be achieved through satellite links. Interactive computer-based systems will synthesize real-time fire information to assist fire managers in making technically complex decisions.

Rapidly advancing technologies promise solutions to fire management information needs and the development of the next generation fire detection and mapping system.

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REFERENCES

Dutzi, Elizabeth J.; and others. 1984. Forest fire advanced system technology-functional requirements. Internal Document D-1600. Pasadena. CA: Jet Propulsion Laboratory; 19 p.

Enmark, Harry. 1984. Fire logistics airborne mapping equipment (FLAME) final report. Internal Document. Pasadena. CA: Jet Propulsion Laboratory; 8 p.

Hirsch, Stanley N.; and others. 1968. Project FIRESCAN fire mapping final report. Res. Paper INT-49. Missoula, MT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 40 p.

Nichols, J. David; Warren, John R. 1986. Conceptual design study: forest fire advanced system technology (FFAST). Publication 86-5. Pasadena, CA: Jet Prop ulsion Laboratory; 90 p.

Warren, John R.; Wilson. Ralph A. 1981. Airborne infrared forest surveillance--a chronology of USDA Forest Service research and development. General Technical Report INT-115. Washington. DC: USDA, Forest Service; 32 p.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Prescribed Fire Versus Air Quality in 2000 in the Pacific Northwest[1]

David V. Sandberg[2]

Abstract: In 1970, it was widely assumed that by 1980 in the Pacific Northwest, prescribed fire would be a thing of the past. By 1985, however, half way from 1970 to the end of the century, the area treated by fire increased. Now, the demise of forest burning is widely expected to occur by the year 2000. Can, and will, a compromise be found between the resurgence in appreciation for fire and the continuing public pressure for improved air quality? The conflict is manageable, provided the current cooperative attitude between forest and air resource managers persists. A 50 percent emission reduction by 2000 seems likely, and 70 percent seems possible, according to projections by fuel managers in the Region.

In 1970, it was widely predicted in the Pacific Northwest that by 1980, prescribed fire would be a thing of the past. The Premier of the Province of British Columbia promised a cessation of slash burning by 1975. Smoke Management was a program that would preside over the phaseout of slash burning. The public demand for air quality would overshadow the forest industry's insistence that catastrophic wildfires would be the inevitable result from a cessation of burning. Other than the threat of wildfire, foresters perceived little threat to productivity. They would have transformed to second-growth management with little or no residues to contend with. Private landowners had largely eschewed fire use, and only the Federal land manager with high-elevation decadent stands would have a compelling reason to burn for site preparation.

By 1985, half way from 1970 to the end of the century, the area in the Pacific Northwest treated by fire had increased substantially. Only a rudimentary smoke management program has been established in British Columbia. Smoke management programs in Washington and Oregon dominate all other considerations in planning prescribed burns, but smoke management has enabled a larger and more effective burn program than before. Hazard reduction has been discredited as a reason to treat slash, yet private landowners have dramatically increased fire use. Only the public sector uses less fire, especially by discontinuing fire for high-elevation site preparation.

Now, the demise of forest burning is widely expected, for the same reasons, to occur by the year 2000. The National goal in the United States to protect visibility impairment in Wilderness, concern for air toxics, and the increasing relative contribution of fire to air quality problems have focused intense regulatory pressure on the practice. Can and will a compromise be found between the resurgence in fire use and the mounting pressure for air quality?

CLEAN AIR, FIRE, OR BOTH?

Smoke management in the Pacific Northwest is a success story. The air resource management agencies, the smoke management coordinators in the State forestry departments, Federal land management agencies, and private industry have

[1]Presented at the Symposium on Wildland Fire 2000. April 27-30, 1987, South Lake Tahoe, California.

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worked together to find ways to reduce emissions while accommodating a growing prescribed fire program (Sandberg 1984). Forest managers have used an array of techniques to reduce emissions without reducing the area treated with fire. Improved utilization of residues, meteorological scheduling (or "spring burning" when the large woody fuels and duff are too wet to burn), mass ignition, and more selective fire use has been shown to reduce emissions by about 30 percent since the baseline period of 1976 through 1979 (Sandberg 1987).

The National goal to predict visibility impairment in Wilderness has been translated to a regional goal of reducing smoke emissions by 50 percent before the year 2000, therefore, the central question is: can smoke be reduced substantially without distorting forest management goals for the rest of the century? With a history of less-than-accurate forecasting, the author and a group of forest managers in the Pacific Northwest Region of the Forest Service, U.S. Department of Agriculture, predict the future of prescribed fire and air resource management in the year 2000.

Fuel Managers' One Vision

Fuel managers in each of the 19 National Forests in Washington and Oregon were enlisted to create a vision of utilization practices and fire use in the year 2000. The vision is needed to complete an Environmental Impact Statement being prepared by a Vegetation Management Interdisciplinary Team under the direction of Gary Larsen at the Forest Service's Regional Office in Portland, Oregon.

Fuel managers were not asked about air quality. Rather, they were asked to consider the Forest Plans and to use their intuition to describe the many distinctly different prescribed fire situations they might encounter.

Each "situation" was defined by a fuel type (e.g., hardwood timber harvest, second-growth short-needled conifer slash, pine-needle litter, etc.). harvest type (e.g., clearcut, clearcut-and-YUM[3], no harvest, etc.), and fire type (broadcast burn, pile burn, etc.). After the responses were sorted and combined. 211 distinct fire situations were identified.

[3]Yard Unmerchantable Material.

Each fuel manager was then asked to describe the current and envisioned burn program for each of the fire situations. The description included a profile of the fuelbed (e.g., loading of residues 3- to 9-inches in diameter, thickness of the duff and litter, height of live vegetation, etc.), and how the fuel loading is expected to change by the year 2000. Then the number of acres treated were estimated, with the future acres estimated under several alternative vegetation-management scenarios ranging from unrestricted fire and herbicide use to severely restricted. Finally, the distribution of burning by month, age class of slash (months of drying since harvest), and ignition method were described for the current period and for each alternative in the year 2000.

Fire Researchers' Other Vision

Fuel managers' responses were all processed in a large spreadsheet program that contains all of the biomass-consumption and emission-factor predictive equations developed over the years by the author's research project. The same equations are routinely used by foresters to plan prescribed fires and by the States to compile emission inventories in Oregon and Washington (Sandberg and Peterson 1985). The result is an array of predictions for the annual yield of smoke emissions for each National Forest and an analysis of what management practices (area burned, level of utilization, and scheduling for higher fuel moistures) will differ from current practice.

All National Forests in Washington and Oregon projected changes in harvest levels, fire use, utilization standards, and burning schedules, or all of these, to reduce emissions from current levels according to the scenario derived from the preferred alternative(s) in each of the Forest Plans. Only 1 of 19 Forests expects to increase emissions under any of the scenarios owing to a large expected increase in th6 treatment of natural fuels to enhance wildlife habitat.

THE VISION: BOTH CLEAN AIR AND FIRE USE IN 2000

Prescribed fires on National Forests in Washington and Oregon currently produce about 56,000 tons of fine particulate matter per year from 226,000 acres. Oregon accounts for 69 percent of the total smoke production. The biomass consumed per acre averages 65 tons per acre on National Forests in western Washington, 54 tons per acre in western Oregon, 44 tons per acre in eastern Washington, and 29 tons per acre in eastern Oregon.

In the Region, we expect at least a 37 percent reduction in emissions from prescribed fires by the year 2000. Expected reduction in the area burned will reduce emissions by 17 percent, and expected declines in the biomass consumed per unit area will decrease emissions by 25 percent. About one-half of the decrease in biomass consumption will result from improved wood utilization, and the other half from scheduling burns for wetter periods.

A 37 percent reduction of emissions before the year 2000, coupled with the 30 percent reduction already observed since the baseline period, would easily exceed the goal to reduce emissions by 50 percent. Emissions will decrease by 19,000 tons just from changes on the National Forests. Of course, these estimates are preliminary and will be refined and reviewed by the EIS Team and compared with the Forest Plans. Also, the emission reduction goal includes all land ownerships, while this analysis considers only the National Forests. Nonetheless, we can have clean air and prescribed fire too, without drastic departure from current forest management goals.

THE VISION COULD BE OVERULED

The vision is based on the quality of projection the fuel managers surveyed. If they are wrong, either by error of judgment or unforeseen future actions that overrule their vision, the conflict between fire use and air quality will be renewed. There are larger issues ranging from market forces to global climate change that are simply too vague to consider. There may be management policies that put higher priorities on potential health risk from exposure to smoke or potential productivity loss from extra utilization that will overrule the present compromise between foresters and air resource managers.

THE VISION DEPENDS ON FUTURING

We can form a vision either from global perceptions or stepwise analysis of smaller components of change. It is easy to perceive a global scenario where we will no longer use fire in forest management. In 1970, our global prediction was for the cessation of fire use, but we never verified the small components of change that would complete that vision. We promised the public the end of fire use, but left the fuel manager with no way to achieve it. We were wrong, and there is no need to repeat the mistake.

"Futuring" is popular and, as managers, we make many lasting decisions based on our vision of the future. Before we bargain away the use of fire or resign ourselves to its loss, we need to consider the responsible fuel manager who deals by necessity in the stepwise analytical environment.

Fire research has yielded a process that can focus our vision a little by breaking it down into smaller components and using a quantitative scheme to reduce the information. Predictive algorithms for biomass consumption and smoke production are used in a process that is compatible with the way we inventory emissions and plan the year's burn activity--the repeatable process that can be updated with new information or opinions.

My conclusions, based on current opinion and knowledge, is that forest managers and air resource managers can continue to work together to achieve air quality goals in the Pacific Northwest without departing from planned forest management and fire management programs.

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REFERENCES

Sandberg. D.V.; Peterson, Janice. 1985. A source strength model for prescribed fires in coniferous logging slash. In: Proceedings, 21st annual meeting of the Air Pollution Control Association, Pacific Northwest International Section, 1984 November 12-14. Portland. OR: Air Pollution Control Association. 10 p.

Sandberg, David V. 1984. Research leads to less smoke from prescribed fire. In: Proceedings, annual meeting of the Northwest Fire Council; 1983 November 21-22; Olympia, WA. Portland. OR: Northwest Fire Council; 107-121.

Sandberg, D.V. 1987. Progress in reducing emissions from prescribed forest burning in western Washington and western Oregon. In: Proceedings, 23d annual meeting of the Air Pollution Control Association, Pacific Northwest International Section, 1986 November 19-21; Eugene, OR: Air Pollution Control Association. 13 p.

Research Response and Needs
(*What do we need to know?*)

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Smoke and Air Resource Management--Peering Through the Haze[1]

A. R. Riebau and D. G. Fox[2]

Abstract: This paper presents a vision of the future rooted in consideration of the past 20 years in the smoke and air resource management field. This future is characterized by rapid technological development of computers for computation, communications, and remote sensing capabilities and of the possible societal responses to these advances. We discuss intellectual developments that we foresee and the likely manner in which these will be realized in the form of new tools available for air resource management. Finally we anticipate a changing climatic and political environment and we discuss the implications of this change on air resource management in general and on land management options associated with these changes in particular.

Fifteen years ago, the first microprocessors appeared for implementation in stand alone, single user, single process computers. Approximately 10 years ago, simple steady state Gaussian dispersion models were introduced as regulatory tools. The application of these regulatory approaches to smoke management from prescribed fire was foreseen in the Southern Forestry Smoke Management Guidebook (U.S.D.A Forest Service 1976) and applied in the USFS Smoke Management Screening System of the Forest Service, U.S. Department of Agriculture (1983). Finally, the first regulatory authority approved model, the Simple Approach Smoke Estimation Model (Bureau of Land Management 1987), appeared in Wyoming on Data General Desktops and microcomputers.[3] With the advent of the Bureau of Land Management Initial Attack Management system (IAMS) in 1985, fire managers were able to view map-compatible, real time graphic presentations of lightning strikes and weather information. During the next 15 years, the increasing power of the microcomputer will allow the development of integrated smoke dispersion modelling systems coupling fire emissions and behavior models, real time meteorological data, mesoscale terrain, wind field simulations, and dispersion trajectory analyses into desktop fire management tools.

The 1970 Clean Air Act introduced a conceptual basis for air resource management which has been refined and revalidated through subsequent amendments. The Act introduced the State Implementation Plan (SIP) to allow individual states to achieve federally mandated air quality goals in whatever manner they deemed most appropriate. The 1977 Amendments to the Clean Air Act maintained this posture and established the dual concepts that esthetics are

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[3]Mention of trade names and commercial enterprises or products are for information only. and do not imply endorsement by the sponsoring organizations.

deserving of protection (visibility) and that ecosystem health, not just human health, is to be protected. This protection, accomplished through the establishment of Class I and Class II areas, is implemented by federal land managers making decisions about the adversity of potential air pollution effects on the ecosystems they manage.

The next 15 years will probably not see much change in these current philosophies, but new environmental goals will be added. It is likely that the need for world-scale regulation will become obvious. In particular, we anticipate global CO_2/greenhouse gases ambient standards being put forth as a result of concerns about global climate change. By the year 2000 this standard will be one of a series of standards which will address not only global carbon balance but also the disposal and handling of toxic/nuclear wastes and other issues. At the very least, these standards will be voluntary on an international scale, but they will likely be mandatory in the developed industrial nations.

Population growth, especially in the Third World, is predicted to swell the world population to 6 billion by 2000. The 1 billion increase over the current world population is dramatic when played against the world population at the turn of the 19th century--l billion people. Although U.S. population will remain stable or decrease, the pressure of population increase will be felt everywhere. In particular, it will be experienced in the quality of the environment. A paradoxical fact will be that the amount of statutory wilderness in the United States will have grown continuously along with increasing world population and we will be among the world leadership in environmental protectionism. Increasing recognition or world public opinion related to strengthened world governmental structures will guide our environmental affairs.

What will the goals of U.S. smoke management be in 2000? They will be the same as they are today; namely, to manage the smoke generated from various types of prescribed fire to minimize its deleterious effects on the public. Biomass burning, however, will be considerably more controversial in 2000 than it is today. The demographic trends of increasing suburbanization and population growth in the South and the West established in the 1970's and 1980's will continue and be encouraged by decentralized office and work structures. Thus, "urban" people will be living in association with forests and hence smoke will cause, at least, the opportunity for increasing conflict.

REGULATORY CHANGES

While we will be dealing with regulations of toxic materials (discussed in some depth by D. Haddow at this conference) as well as continuing to be concerned about inhalable particles, the environmental issue of concern will be CO_2 and greenhouse gases. Since it is possible that in this time frame we will see movement away from a "carbon" based energy system (Barker 1987), it also seems that biomass burning will be heavily regulated. A likely result of the International Geosphere/Biosphere Program of research could be the verification that forest burning releases significant amounts of CO_2 and other greenhouse gases into the global atmosphere. Global CO_2 concentration increases will be, if not regulated, at least a major concern. Permits to consume biomass will be carefully allocated nationally and the need for precise smoke management will be present all over the contiguous United States. Forest burning might be among the only components of the global carbon cycle that can be manipulated. Thus, as a means of controlling CO_2 and greenhouse gas buildup, biomass burning could be heavily regulated.

Accentuating and underscoring the public life of all environmental issues will be the increased education level and increased international awareness of the general public. These factors will influence the political life of humankind toward attitudes even farther away from natural resource exploitation. The public will come to regard, more and more, that potential accentuation of global climate change through biomass burning is a morally unattractive activity. It will also regard the creation of a hazy or smokey atmosphere through particulate releases from prescribed fire as a signature of poor management. It will demand absolute minimums of smoke intrusions. The current laws in place in states like Oregon and Washington likely will be extended to other parts of the country. Smoke management and planning to avoid visibility impairment will be an integral part of the burning of forests, forest production wastes, and rangeland vegetation for management purposes.

MODEL DEVELOPMENT

Richardson (1965) was the first to consider that the atmosphere could be modeled by the solution of the equations of conservation of mass, momentum, and energy (hydrodynamic equations). The computation time, however, was a major limitation. Richardson estimated that if data on the state of the atmosphere could be made available within a few minutes to a room full of "computers," individuals with pencil and paper ready to calculate, the new state of the atmosphere could be calculated in an hour or so. It would only require 256,000 of these "computers"! In the early 1940's, John Von Neumann utilized the first digital computers to solve hydrodynamic equations. By the late 1940's and early 1950's, the first numerical models of global weather circulation were appearing. Owing to the quasi-two dimensionality of the atmosphere on a global scale as well as the overwhelming influence of certain low wave number instabilities, these computations were deceptively successful.

Weather prediction, using computer generated global circulation patterns, became operational in the 1960's. The quality of meteorological modelling has increased steadily ever since.

Since the popularization of computers in the 1960's, there has been increasing use of mathematical techniques to simulate natural behavior. While the general global circulation appears to be a very complex problem, and a laborious computation taxing even the most capable of super computers, it is a well posed mathematical and physical problem. There are no really fundamental problems, except the collection of data to drive the model, the parameterization of important physical processes like cloud formation, and the treatment of boundary conditions and "sub-grid" scales of motion, to implementation of global scale models. Increasingly we have been encouraged by the successes of computations on global atmospheric dynamics and have tried to venture forth in improving the boundary condition parameterization and "subgrid" scale representations.

All of these areas have proven to be major challenges to modelers. In general, they involve turbulent, three-dimensional motions. The turbulence problem is as yet unsolved; hence, any modelling involving turbulent flows must be of an approximate and heuristic nature. Turbulence is stochastic so that individual realizations of a flow field are uncertain and somewhat meaningless. The only predictive skill associated with turbulence comes about from ensemble averages and is only realistically characterized by wide variances and hence large uncertainties. Parameterization problems are largely associated with these difficulties as well as problems of scale. In the three-dimensional turbulence flow of the atmospheric boundary layer, the scales that should be resolved for a correct simulation range from $1x10^{-2}$ m to 10^{4} m, or six orders of magnitude! To conduct computations on a grid with 10^{6} resolution in each dimension would involve 10^{18} nodes. This is even beyond the capacity of super computers. Thus, any modelling done for the purpose of simulating atmospheric flows and their effect on the dispersion of smoke are going to be approximate and subject to large uncertainty. Also, it is very important to remember that because of the stochastic nature of atmospheric turbulence, individual realizations, that is trajectories of smoke from individual fires, will never be predicted with much skill. Any model will need to be verified by comparison with real flows and smoke plumes. The next 20 years of research into atmospheric turbulence should provide a much improved estimate of the degree of skill that might be achieved in predicting smoke behavior.

Modelling the dispersion of pollution in the atmosphere was originally attempted for military purposes and to support concerns about the distribution of radioactive materials in the atmosphere. These models were based on the assumption that the downwind distribution of contaminants could be approximated as a Gaussian distribution. The Gaussian parameters were modelled as functions of distance from the source and atmospheric stability. This development originated in the United Kingdom by Frank Pasquil and in the United States by Frank Gifford and has been in use ever since. Although computer advances have refined this basic concept, it remains the current approach for at least first order modelling. It is very likely this will still be the case in 2000.

The challenge of predicting pollutant dispersion for regulatory purposes started with the 1970 Clean Air Act which introduced the State Implementation Plan as an air management technique. SIP's required projections of the effectiveness of regulatory policies which, in turn, required the use of modelling. The 1977 Amendments specifically addressed modelling which required the Environmental Protection Agency, (EPA) to issue a modelling guideline and approve certain models for regulatory applications. All the models approved in the 1977 (first) edition and all those approved in the current (1986) edition of EPA's modelling guideline are Gaussian-based.

Associated with regulatory permitting problems in the late 1970's and early 1980's, a major effort was launched to understand and improve on the prediction of dispersion in complex terrain. This effort is still underway at this writing. It has led to the recognition of the role of atmospheric stability in complex terrain and the development of regulatory models which consider terrain in more or less simplistic ways. In the next 10 years, regulatory models with improved formulations that take advantage of this knowledge will be available and will greatly improve the prediction of concentrations in mountainous areas.

The major problem in predicting smoke dispersion in complex terrain will still be that of predicting the flow pattern. As stated earlier, this will remain a major complication. New super microcomputers will allow models such as the Topographic Air Pollution Analysis System (TAPAS) 3-D Wind Model (NUATMOS) to be applied at the user's desk. This will lead to an improvement in model ease of use, availability, physical presentation of results, resolution and mathematical sophistication. The problems that will remain will be:

--boundary conditions
--initial conditions
--turbulence and uncertainty
--topographic resolution.

Boundary conditions simulation will be a very active area of research, but its treatment will be a major limitation in the prediction of smoke dispersion. We will still in the year 2000, most likely, be parameterizing the surface energy balance in a very crude manner. The boundary condition problem will lead to difficulties in predicting transition flows and valley stagnation episodes.

Initial conditions will need not be a major problem, but the cost of properly generating them may be too high. Remote sensing instrumentation such as doppler radars and lidar systems, as well as the doppler acoustic sounder (probably considered as the old standby by the year 2000), will be available and linked to computers to initialize map compatible calculated windflows at isolated locations. These instruments will be costly and, although mobile based systems will be deployed for major prescribed fires, there will not be enough of them to go around. The initial condition sensing density will not be sufficient to do an optimum job.

Turbulence, as we stated earlier, is a cause of uncertainty in any consideration of the dispersion of pollutants. The problem is that ensemble behavior, that is the mean condition, provides only a rough indication of the specific realization that is either predicted or observed. Thus, no matter how well the mean condition is simulated or predicted, it will be imperfect and in some detail incorrect. This fact leads to the presence, in any calculation, of an inherent uncertainty. We are only now coming to accept this fact and to develop techniques that for example might calculate the inherent uncertainty and thereby provide the user of model results with a window of believeability. While this will be a major thrust of dispersion modeling in the coming years we will be slow to leave the relative comfort of our deterministic mind set. We expect to see the beginnings of a stochastically oriented approach toward smoke management by the year 2000.

Topographic resolution can be solved if we are able to pursue the current trend in Geographic Information Systems (GIS). To the extent the smoke management modelling can be coupled with such systems, the terrain resolution problem will cease.

In summary, we envision the smoke management model of 2000 to be not substantively different from the NUATMOS (3-D wind field) model currently within TAPAS. This will be coupled with a 3-D particle and cell type dispersion model which will be able to generate reasonable 3-dimensional dispersion patterns. Additionally, NUATMOS type models will be supplemented with a drainage flow generator based on a direct simulation of the energy balance at the earth surface and forest canopy. This drainage flow model will be capable of predicting the distribution of smoke released from the fire as partitioned between, within, and above the forest canopy component. In addtion [sic], we will be providing users with an estimate of model uncertainty as well as other results.

COMPUTER ADVANCES

In the early 1970's microcomputing as we know it today did not exist. About 1971, the INTEL Corporation released the 4004 microprocessor for a limited number of experimenters. This was a four bit microprocessor operating at less than 1 MHz clock speed. In about 1974 microcomputers appeared utilizing the INTEL 8800 processor; an eight bit device operating at 1 MHz or better. These microcomputers had 1 or 2 kilobytes (Kb) of random access memory (RAM) and used a punched paper tape for mass data storage. Paper tape as a mass storage device was soon (about 1976) replaced with cassette tapes for storage of data and programs.

In 1976 or thereabouts, a new era in microcomputers was starting. Apple Corporation released the Apple I (and soon after the II) which, it could be argued, did more to popularize the concept of personal computing than any other machine introduced before or since. The Apples (based on the 6502 processor) along with their Z80 based cousins, ushered in a period when users become both more involved with the small machines and more demanding in expectations for performance. Cassette tapes were soon discarded for floppy disk drives that held a whopping 64 Kb of data. RAM went from the 16 Kb size to 64 Kb with upgrades. The 64 Kb floppy disk was soon too small; users demanded more.

In response, the industry quickly changed its offerings. In 1979 the Apple II+, the Super Brain and various other eight bit, 2 to 4 MHz machines offered 64 Kb RAM and 160 Kb floppy disks standard. The CP/M operating system was in its heyday and new compilers and application programs were constantly being offered. In the period from 1979 to 1981 mass storage mania was soothed with the introduction of very expensive Winchester hard disks for microcomputers. In 1981 the IBM PC was born; a more or less true 16 bit microcomputer operating at a high enough clock speed, so that it was capable to handle and store enough data that scientists started to become both interested and addicted to small machines. Now, in 1987, true 32 bit machines with megabytes of RAM (proportedly gigabytes with the Apple Mac II) are emerging on the scene. These machines promise huge processing capabilities housed in an easily accessible user interaction environment.

By the year 2000 the microcomputer and its application software will dramatically improve from that available on today's newest 80386 or 68020 machines. This means that beyond a doubt the fire manager will have new power at his or her disposal to access fire emission data and meteorological data, and perform emission, dispersion, and air resource impact calculations.

TECHNOLOGY USER RELATIONSHIPS

Perhaps one of the most remarkable changes in understanding information has been the inclusion of simple graphics in integrated small computer programs. Nowadays, most good computer database and spreadsheet programs employ computer graphics. Computer graphics have become so pervasive that we take them for granted in all phases of data presentation.

By the year 2000 and beyond our expectations of appropriate graphic presentation of data will be drastically different. We will expect graphics to be interactive; one will be able to focus on specific pieces of graphic presentations and expand, reorient, or otherwise manipulate them to gain insights. For the smoke manager, this will mean three-dimensional presentations of smoke plume trajectories and concentration footprints that will be almost infinitely manipulatable. In addition, real time weather data could continuously be displayed and be used to adjust plume trajectory representations. These graphic representations will also be used to educate and inform the public as to the application of prescribed fire and its environmental impacts. The graphic representation of projected environmental impacts will become a common place tool for the land manager as current geographic information system software and data bases mature; the public will come to expect full graphical disclosure of land management information from its public land administrators.

Finally, the complexities of using these types of systems and large data bases will be moved farther and farther into the background of computer operating systems. By 2000, multitasking and parallel processing will allow implementations of expert systems that, utilizing artificial intelligence programming techniques, will allow fire managers to accomplish tasks of great complexity with minimum supervision. The hardware and software will not take care of themselves, but they will allow data collection, data analysis, and mathematical simulations to progress while the fire manager looks to other issues. Thus, a variety of constantly updated and improved information will be available to the fire manager, and perhaps the public also, at a moment's request.

CONCLUSIONS

Land managers are ecosystems managers. They are also technology managers. How well they will be perceived as managing both ecosystems and technology will rest largely on how well they assess the trends which will drive public opinions. We believe the next three decades. will be characterized by a growing public expression of global awareness and responsibility. The nuclear war issue will continue to influence this viewpoint, but global climate change may hammer out the interdependency of nations in the environmental sphere. We foresee the pattern of social trend as being toward international interdependence, cooperation, and ultimately international regulation.

IN THE YEAR 2000

Modelling of the dispersion and chemical interactions of fire released air contaminants will be a part of day-to-day fire management activities. First approximations of smoke impacts will still be most probably made using gaussian techniques modified for terrain influences. The major problem in predicting smoke dispersion will still be that of predicting three dimensional flow patterns. The increasing power of microcomputers will allow complex models, such as the TAPAS NUATMOS model coupled with an appropriate 3-D dispersion model, to be executed at the desk top. There will still be lack of skill in predicting actual smoke trajectories from individual fires, but users will come to understand estimates of model uncertainty along with other model results.

The gradual and inevitable spread of mass communications will foster the planetization of mankind's viewpoint. The increasing involvement of women and minorities in professional life will change the perception of dominance over the environment to one of stewardship and managing for diversity. In the end, but perhaps not by the year 2000, universal education will cause the fire manager to become subject to rules which will be international in scope and multigenerational in vantage. Technological improvements will serve this scope and vantage point, and allow both public review and involvement in smoke management process and activities on an almost real time basis.

REFERENCES

Barker, B. 1987. The world of 2006. Palto Alto, CA: Environmental Protection Agency Journal 11: 4-24; 1987 March 2. Environmental Protection Agency. 1986. Guideline on air quality models (draft). Research Triangle Park: Office of Planning and Standards.

Richardson, Lewis F. 1965. 1922 Weather prediction by numerical process. New York: Dover Publications; 236 p.

Riebau, A.R.; Fox, D.G.; Sestak, M.L.; Dailey, B.; Archer, S.F. 1987. Simple approach smoke estimation model (SASEM). U.S. Department of Interior. Bureau of Land Management. Unpublished draft supplied by author.

Turner, D. 1970. Workbook of atmospheric dispersion estimates. Research Triangle Park: EPA. Office of Air Programs Publication No. AP-26.

U.S. Department of Agriculture. Forest Service. 1976. Southern forestry smoke management guidebook. Gen. Tech. Rep. SE-10. Macon, GA: Southern Forest Fire Laboratory.

U.S. Department of Agriculture, Forest Service. 1983. Personal conversation with Lee Lavdas, Southern Forest Fire Laboratory, Macon, Ga.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Forecasting, Forecasting[1]

Michael A. Fosberg[2]

Abstract: Future improvements in the meteorological forecasts used in fire management will come from improvements in three areas: observational systems, forecast techniques, and postprocessing of forecasts and better integration of this information into the fire management process.

A look at the role that meteorology will play in fire management in the year 2000 is really a look at the science and art of fire management, and only in part at what the science and technology of the atmospheric sciences will be able to provide to meet those management needs. To discuss the atmospheric sciences and technologies for the year 2000, assume what fire management needs will be. Since I take on the dual task of forecasting fire management needs as well as the supporting science and technologies of the atmospheric sciences, I will begin by describing the forecast process itself.

The first step in forecasting is accurately assessing the current situation. In the atmospheric sciences, this involves comprehensive observation and analysis of the current weather. I will assume here that a full understanding of current fire management is also required to forecast the future; for example, how priorities are established in dispatching crews and equipment when resources are limited. In the atmospheric sciences, physics dictate an orderly, albeit sometimes rapid, change to a new situation. This physical memory of the past has, I believe, an analog in management.

The second step in forecasting is identifying and quantifying those forces that will produce change. For example, how rapidly will tropical moisture move northward into the Rocky Mountains and produce lightning-started fires? Or, when will the upper air trough move onshore, and when will the Santa Ana wind decrease? Again, I believe that there is a predictable, parallel process in fire management in which a given starting point and a rate of change can be used to predict the future. In this case, they are not based on Newton's laws, but are of equal importance in producing change.

I identify here only three of the possible forces of change in fire management. First, economic use of crews, equipment, etc., on a national scale is a strong force. Pre-positioning of shared resources, i.e., crews and equipment, based on weather forecasts is one example. Fire intelligence will need potential fire severity forecasts on a national scale from a range of 1 week to 1 month. Second is the need for emergency response when life and property are immediately threatened by wildfire. The urban-wildland interfaces--such as the Los Angeles Basin, suburban Hobart and Mount Wellington, the Wasatch Front of Utah. the Dandenongs of Melbourne, and the front range of Colorado--have rapidly been urbanized. There, traditional wildfire fuels combine with high value structures and, frequently, with limited transportation systems. Rapid deployment and dispatch of fire crews and equipment may need to

[1]Presented at the Symposium of Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

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be supported by short-range forecasts or emergency response meteorological support activity. The third management force is in continued support of fire danger on the short-time scales. Forecasts of specific manning and action levels of preparedness will probably not change.

The third step in forecasting is adding or subtracting the accumulated change to or from the initial assessment of the situation. If the initial assessment was correct, and the quantitative evaluation of change was correct, then the initial value plus the change should produce a perfect forecast. The initial assessments of both meteorology and management, however, are imperfect. Also, imperfect are the assessments of change.

Given this imperfect initial state and imperfect forecast of change, what is the value or information contained in the forecast? Given a perfect analysis of the current or initial state, the ability to forecast change decreases rapidly as the forecast period increases. Also, the spatial resolution of those weather forecasts tend to contain only information for large areas as the forecast period increases. At what uncertainty in the forecast, either in time or in spatial resolution, does the forecast contain no useful information? When does a fire manager decide to bet on climatology rather than the forecast?

Using this summary of the forecast process, the initial state, the forces of change, the final state, and the value of information, I will state the three assumptions I have imposed on fire management:

1. Economics will dictate sharing of resources between geographic areas--a national fire intelligence system will be using meteorology more effectively.

2. Fire emergency response centers will integrate meteorology into the decision process.

3. Information content and quality of forecasts will be integrated into the decision process; i.e., probability forecasts.

Given these three assumptions and the forecast process described above, I will address the topics of observations, forecasting, and use of weather information.

Under the Observational System. I address the probable state-of-the-art in assessing the current situation; under Weather Forecasting, the tools that will exist or will be needed to provide an assessment of the future; and under Using Weather Information, how one might use these forecasts in fire management.

THE OBSERVATIONAL SYSTEM

Recent procedures in observing weather for fire management were based on manual techniques of reading dials and gauges, weighing fuel sticks, and categorically describing the sky. Of necessity, these weather observations were made only where and when personnel were available. As a result, the observations were seasonal--namely during the fire season--were limited to nominally once per day, and were occasionally not available when personnel had higher priorities. Observations of upper air winds and temperature (stability) to support smoke management decisions were usually at locations far removed from the sites of prescribed burns. Also, the variations of upper air winds and stability induced by complex terrain further reduced the information content of these weather observations. Lack of reliable upper air winds data and temperatures also prevented prediction of probabilities of crown fires or long-distance spotting. In essence, the limited weather observing system gave both fire managers and weather forecasters an imperfect assessment of the initial situation to which the forecast changes were to be applied. Simply stated, a perfect forecast of change applied to an imperfect knowledge of the current situation will lead to an imperfect forecast.

What currently in development or research stages will allow a more accurate assessment of the current state of weather? Four significant activities all noted here. First is the development and deployment of remote automatic weather stations (RAWS) (Wolfson 1987). These surface-based weather observing platforms do not require personnel and, therefore, may be placed where observations are most needed. RAWS transmit data through geostationary satellites to a central receiver at frequent intervals. A network of RAMS properly deployed provides frequent weather observations at critical locations and, therefore, improves assessment of the current situation. Second, is the development of the automated lightning detection system (Vance and Krider 1978). Like RAWS, the lightning detection system provides temporal and spatial weather information and is fully automated. A third type of system under development is designed to provide upper air winds. These systems, NEXTRAD (Next Generation of Radar) and Profile (Durham and Wilk 1987, Chadwick and Hassell 1987), are also automated and have data telemetry capabilities. These three fully automated data collection systems for surface weather, upper air winds, and lightning detection have real-time communication capabilities to both centralized and dispersed decision centers. These systems are the observation platforms of the future, which will provide a more accurate assessment of the current weather.

Unless these data collection systems are deployed correctly, however, we still may inaccurately assess the current situation. This leads to the fourth significant development and research activity in weather observations. That is, determine how many of these data collection platforms are needed and where to obtain the desired level of assessment of current weather? The first three activities described above are primarily engineering activities. This fourth development addresses data sampling procedures, information content, and acceptable margin of error (Fujioka 1986; Jacobson and Brucker 1985). In particular, I will describe a current research program to obtain optimal weather station deployment.

The first step in determining where to locate weather stations is to define those weather elements, or combination of elements, that are critical to the operational decision. An example of where these sampling techniques might be used are in designing air quality networks of sampling locations to determine total air pollution burden. Another example is in designing rainfall measuring networks for water yield or flood prediction. A third example, and the one that I will use to describe this process, is for fire danger and fire behavior assessment.

A common means of integrating weather into fire management in the United States is by assigning a manning or action preparedness level to a particular value of burning index. It is determined from the cumulative distribution of historical values of that index. In the United States, the burning index is a measure of fire behavior, in particular the Byram flame length (Byram 1959), and is composed of rate-of-spread of a fire (Rothermel 1972) and the energy output of that fire (Deeming and others 1972). Fire behavior and fire danger are dependent on the nature of fuels; however, my intent here is to determine the spatial variability of weather rather than fuels. The integrating variable for fire management then should take on the meteorological characteristics of the burning index, but exclude variations of that index produced by nonmeteorological factors, namely fuels. For this reason, the target variable is defined as the fire weather index (Fosberg 1978). The fire weather index maintains the appropriate weightings of humidity, windspeed, and temperature, while limiting the effects of fuels variability. Hence, it is an index of weather that is linearly related in windspeed and relative humidity response to the burning index and fire behavior, the target variable for fire management.

Because the spatial variability of weather as well as what the weather is at a specific point are concerns, I introduce the concept of field (spatial) variation. The new term, target field, describes the combination of the target variable and the spatial variation of that variable. In the following example, that target field is the fire weather index, which is composed of temperature, humidity, and windspeed. Procedures to develop a target field are better left to a paper on that specific topic. I will only outline the general procedure here.

Selection of weather events is particularly important in developing a target field. An assessment of weather events or situations in which management decisions are critical are used to determine the data base for the target field, i.e., the decisionmaker has an important role in this process. Examples of significant weather events include the southern California Santa Ana (McCutchan and Schroeder 1973) and the Hudson Bay High of the Lake States (Schroeder and others 1964). Once these critical events have been identified, a variety of objective and subjective analyses of the weather data lead to a quantitative spatial description of the target field. These analysis techniques involve computer simulations of physical processes. statistical analysis of climatological data, and subjective interpretation and adjustments of the target field. The target field is defined in a form consistent with Geographic Information Systems (GIS), in that spatial position of observations and interpolation of those data can be used in a number of analyses. We have chosen to convert the observed target field data to a high resolution Cartesian coordinate grid of north-south and east-west parallel lines, and this digitized data base is then treated as perfect. Nonlinear, optimal interpolation techniques (Fujioka 1986) are then used to find those locations that will minimize the error between the perfect data and the depiction of those points with an assumed number of sample points (weather stations). If 2000 data points are in the GIS and the problem is where to place 2000 weather stations, we would find those locations coinciding with the data base and containing no error. If, more realistically, the problem is where to place 50 or 100 weather stations in that array of spatially distributed data, we would find that the error is not zero. and is greater with 50 stations than with 100 weather stations. The total error in spatial estimates will decrease exponentially as the number of weather stations increases; however, these errors do not decrease uniformly over the geographic area.

Acknowledging error, and that the errors are not uniformly distributed in space, brings us back to management's role in the design of an observational network. The analytical techniques (Fujioka 1986; Jacobson and Brucker 1985) allow the fire manager to develop a number of scenarios. These scenarios are played against the total error and the localized pockets of persistent error. The fire manager can pose a series of scenarios:

1. Number of weather stations that will be installed.
2. External external weather data, for example, National Weather Service (NWS) and Federal Aviation Administration (FAA) observations that will be used.
3. Areas that will be excluded from observation (wilderness areas).
4. Areas where resource values are high and require observations.
5. Alternative sites to minimize impacts of localized error.

In all the scenarios, the fire manager has control of the weather station network design. A proposed 50-fire weather station network for southern California accounts for the NWS and FAA weather observation sites and excludes the Pacific Ocean (conditions 1, 2 and 3 above, fig. 1).

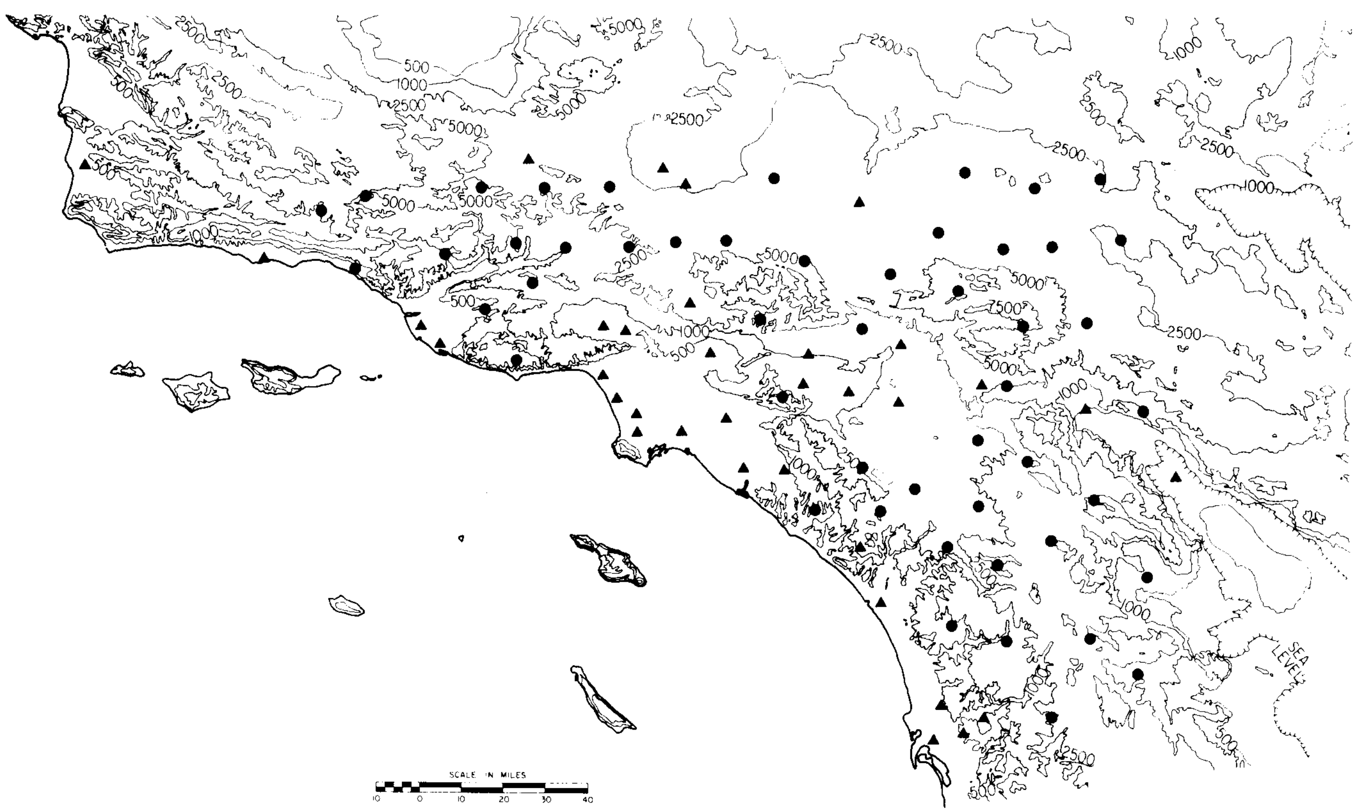

Figure 1--A proposed network of 50 fire weather stations for southern California. Circles represent the proposed network. Triangles represent National Weather Service and FAA observation sites. (after Fujioka 1986)

Siting upper air observational systems to support such activities as smoke management will require extension of existing technologies. One critical need is development of network design procedures that are based on a vector solution for optimizing networks. If a vector solution is considered as a multivariate orthogonal solution, then multiple resource needs can be considered.

WEATHER FORECASTING

The process of forecasting is based on an accurate assessment of current conditions. Research and development on observational systems, described in the previous section, will lead toward accurate assessment of current weather. This assessment is used to estimate the rate of change of each weather element. This rate of change is constant in neither time nor space. For example, near a cold weather front, temperatures and humidities will vary sharply over short distances. Movement of that weather front will result in abrupt temporal changes in weather.

Errors in Forecasting

The observational system improvements described above are not perfect. As a result, the initial assessment of the weather contains some error. Therefore, the forecast has errors due to both starting in the wrong place and going in the wrong direction. These forecast errors do not accumulate at the same rate everywhere. For example, our forecast for tomorrow may be extremely accurate in one location and be totally inaccurate in another. The specific forecast process is to use the initial estimate of the weather (the imperfect observational system), estimate the changes, and then establish a new estimate of the weather. Because of the high degree of nonlinearity in the physical description of the rate of change, this process of initial estimate, rate of change, and establishing a new estimate of the weather must be repeated numerous times to compensate for the nonlinearity of the rate of change, even for a 24-hour forecast. The result is that errors tend to be carried forward in forecasts and because the intermediate estimates of the weather contain errors, the error in the final forecast grows with the time interval of that forecast (Folland and Woodcock 1986; Gilchrist 1986).

If we examine that forecast error growth rate over time, two characteristics of the error are clearly dominant. For high spatial resolution of weather information (on, say, 10-km intervals), the error growth rate is such that no information or skill in forecasts exists beyond a few hours. At larger spatial scales, here information is averaged over a few hundred kilometers, forecasts are available to 3 days. At long, temporal intervals, the order of a 10- to 30-days, skill in forecasting is demonstrated only with both spatial and temporal averaging of the forecast. For example, a 5- to 10-day or 30-day forecast is valid for departures from the norm on a scale of 1000 km. Specifically, those medium- (out to 10 days) and extended-range (out to 30 days) forecasts are statistical departures from normal (i.e., climatology and confidence in that forecast departure). In essence, the information content of a forecast will show an exponential decrease of spatial resolution as the time period of the forecast increases. These limits give us the following: high spatial resolution forecasts are valid only on short time scales, and medium- and extended-range forecasts are valid on only 1000 km scales. Based on current technologies, predictions are not meaningful beyond 90-days prediction (Gilchrist 1986).

Short-range forecasts, commonly called nowcasts (Browning 1982), cover a time interval out to approximately 6 hours. The information content is essentially that contained in the observations. As a result, nowcasting needs to be supported by an intensive observational network of weather stations, particularly in the mountainous West. Emergency response systems, such as those used in the vicinity of chemical or nuclear facilities, are an example of effective use of nowcast concepts. Here, high risk, accompanied with high value, combine to warrant the investment in the observational and intelligence systems used in nowcasting. Nowcasting requires substantial capital investment, in both an observational system and an intelligence center to utilize those observations for management decisions.

Highly accurate forecasts are currently available on a 1- to 3-day period. These forecasts are fully integrated into fire management decisions and little needs to be said here except that the current high level of skill demonstrated in these forecasts, both numerical (computer) and human interpretations, will continue to improve as the observational data base improves.

Forecasts in the medium-range (out to 10 days) and the extended-range (out to 30 days) are beginning to show useful skill in forecasting time and space averaged departures from normal. These forecasts, using both numerical and empirical methods, do not contain high time or space resolution of information. They contain information on the large scale atmospheric structure. The day-to-day variations in weather, which are the result of small (less than 1000 km) variations in the atmosphere are intentionally removed from the forecast process to reach further into the future. Thus, the information content of these forecasts differs greatly from that contained in traditional short-range (3 days or less) forecasts. In fact, the information is more useful when expressed as departure from normal for the medium- and extended-range forecast period. Further, these forecasts are not absolute values of departure, but are probability distributions of departure. While this is a somewhat different format for forecasts than what fire management normally receives, it is particularly appropriate for decisions on where to pre-position crews and equipment. The probabilities of fire severity and the confidence in those forecasts can be used effectively in the decisions. The rapid gains in medium- and extended-range forecast technology are in the quality of the time-space averaged forecasts of departure.

Increasing Spatial Resolution of Forecasts

In some areas, spatial variations of fire severity are relatively small. In the mountainous West, spatial variations of fire severity are large and occur over short distances. Forecasts of probable departures will need to incorporate at least the systematic spatial variations of fire severity into these forecasts. Techniques used to develop weather station networks, in fact, incorporate the systematic variability of weather in the optimization process. Research and development on increasing spatial resolution of weather information, and the rate that weather changes. both temporally and spatially at the mesoscale (100 km) are active topics. There are two general approaches to increase spatial resolution using coarse scale forecasts: (1) nested-grid modeling, and (2) a combination of statistical and objective analysis techniques that are dynamically contained.

Quality of forecasts and, in fact, secondary forecasts can be obtained by nested-grid modeling. This first procedure uses the coarse scale (medium- or extended-range forecast) to establish a local forecast of the large scale atmospheric condition. It then uses high resolution data on terrain variability of knowledge of small scale physical processes, such as the southern California Santa Ana to produce a high spatial resolution forecast. These techniques are currently in use in Europe (Dell'Osso 1984) for medium-range forecast periods. Use of these nested-grid procedures has not been attempted as yet beyond the 5- to 10-day period. Neither have these models been used with varying initial conditions to generate probabilistic forecasts. Instead, these nested-grid models are being used to forecast specific weather events.

The second approach to increase spatial resolution of forecasts uses techniques that combine the preservation of physical concepts with the efficiency of statistical (probability) forecasts without having to solve a large number of nonlinear differential equations on mainframe computers. For example, consider a pure statistical approach to develop high spatial resolution windspeeds and directions at a large number of locations. Unless these wind forecasts are in mass balance, an air quality forecast based on these winds could contain significant error. Here, I use an error trend to absurd levels, only to illustrate a point. Consider the case where mass balance is not conserved in the transport of smoke. Over time, the prediction could lead to smoke concentrations exceeding the density of mercury, or alternatively to a vacuum of air, depending on the direction of the systematic error contained in optimizing on local minimum error in the statistical analysis.

Optimizing on minimum error at each location for which a statistical solution has been obtained, however, may not be the best solution. Using the air quality example above, the optimal solution would be the best point prediction of wind direction and speed that did not violate the physical law conserving mass rather than the minimum error of each point. Such dynamically constrained objective analysis models are rapidly moving into a variety of applications (Fosberg 1984. 1985) in both nowcast and short-range forecasts. These techniques use statistical methods to assimilate data and constrain the spatial and temporal variations by the laws of physics. The nested-grid modeling technique uses statistical methods to organize data and then adjusts the resultant spatial depiction for physical consistency. An alternate method is using the physical principles in a direct solution of the governing equations to develop the high spatial resolution variations, then applying the statistical methods of the model generated data. This approach contains considerably more physics, but most of these models have received only limited validation with real data. Nevertheless, these models are conceptually similar to the global models and, therefore, the uncertainties and confidence in the forecasts should be easier to track through the system.

One type of mesoscale model that can be used in postprocessing to obtain high spatial resolution is dynamically constrained objective analysis. This group of models has been extensively tested with real data (fig. 2) and is being used in emergency response systems and other selected applications. These models, however, require an extensive amount of data to accurately depict small-scale spatial features, and contain no information on rate of change. Considerable effort is being expended to improve the depiction of the physical processes in these models and thereby reduce the data requirements, while retaining computational efficiency (Fosberg 1984; McGinley 1986, Ross and Smith 1985). These improvements in dynamically constrained objective analyses have the potential to be nested spatially within the computationally efficient large-scale models to provide greater spatial depiction at frequent time intervals.

Statistical models, such as those described for weather station network design in the section on The Observational System, can also be used to enhance the spatial information content.

An untested but promising method of increasing the spatial resolution of forecasts through postprocessing is that of a hybrid model combining the statistical covariance matrix techniques with the physically based objective analysis models or the mesoscale numerical simulation models. The physically based models would constrain the statistical spatial variations to physical consistency, i.e., the statistical representation of wind would assure mass consistency and, therefore, could be used

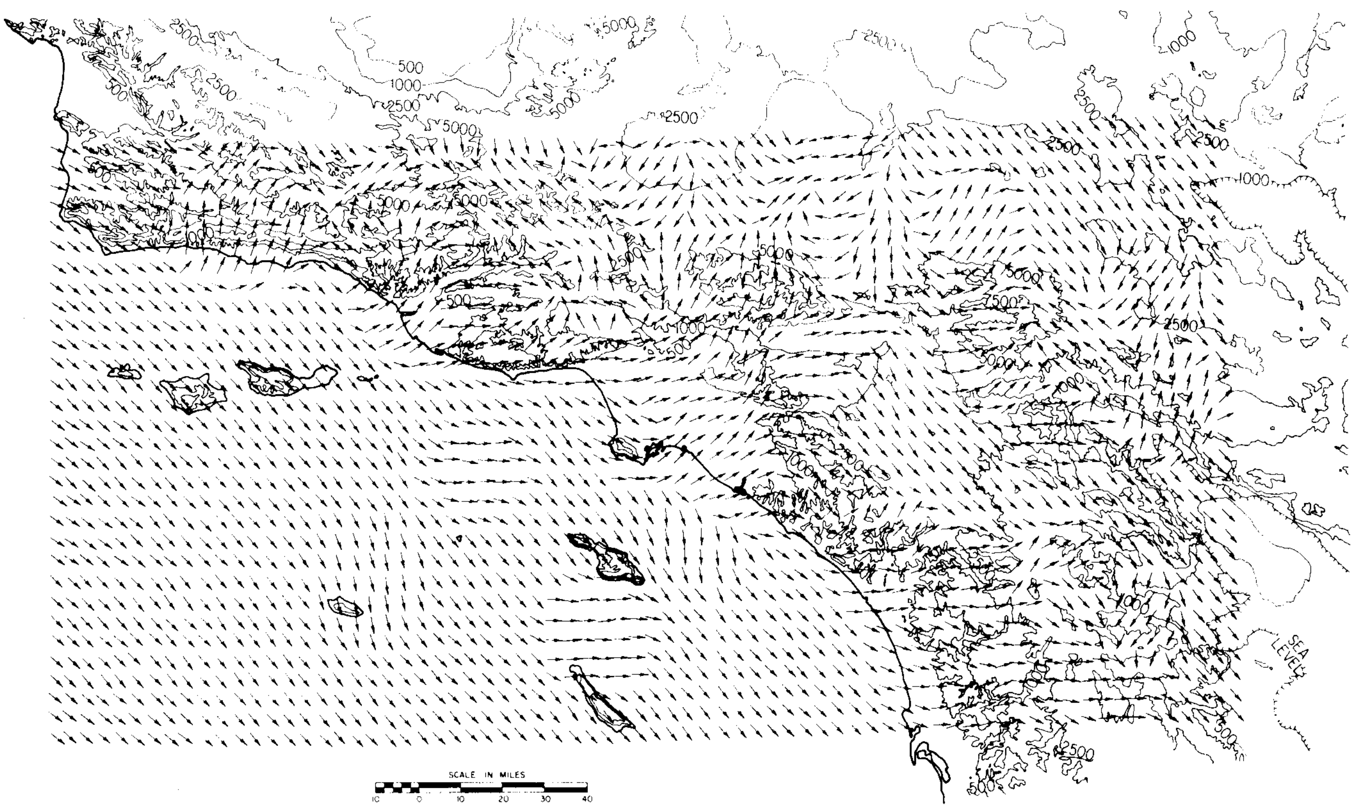

Figure 2--Modeled mesoscale windfield for southern California (after Fosberg, McElroy and Wakimoto 1987).

in smoke management or other air quality applications.

The techniques used to design weather station networks, in fact, contain the statistics of spatial variability of weather. Given this hybrid method of quantiying the spatial variations, one can use the spatially coarse forecasts and add the systematic fine scale spatial variability to those forecasts by the above two approaches (Fosberg and Fujioka 1987).

Postprocessing of Forecasts

Postprocessing is numerical analysis of the quantitative forecasts and takes place in two forms. One form is further meteorological interpretation of the forecasts, a common example being use of nested-grid objective analysis and prediction models. The intent of these postprocessing models is to enhance the spatial resolution of the forecast products. A second form of postprocessing is nonmeteorological: a common example is forecast fire danger.

The meteorological postprocessing most useful to fire management uses mesoscale models. They are designed to depict small-scale atmospheric features (on the order of a few tens of kilometers) and to cover areas a few hundreds of kilometers on a side. Mesoscale models range from statistical representations of the systematic spatial and temporal variations of weather to numerical simulation of detailed physical processes. This postprocessing of forecasts was described in the previous section.

Computer generated forecasts of weather tend to show bias or systematic error as the forecast period increases. These errors arise from several sources and are usually beyond control or correction by users such as fire managers. Two approaches are used to minimize these errors: Perfect Prognosis techniques (PPT) and Model Output statistics (MOS) (Klein 1978). Both are based on establishing regression relations between the forecast output and the observed weather. Perfect Prognosis Techniques are designed to correct statistically the differences between the observed behavior of the atmosphere and the forecastable behavior; that is, this approach removes bias from the incomplete physics in the forecast models. Model Output Statistics, on the other hand, are more general in that the statistical relation is established between the model output and the desired forecast variable. In the case of MOS, the desired forecast variable--such as a measure of fire danger--can be estimated without calculating intermediate meteorological variables. If the forecast model is modified, however, then MOS must be redeveloped because the bias correction is no longer appropriate. The current practice is developing PPT to establish the prediction of the meteorological variables, or fire-danger indicies, and using MOS to correct the model bias. Both PPT and MOS are applicable to empirical and numerical forecast procedures.

Before one can look at meteorological or meteorologically driven fire related products from postprocessed forecasts, the characteristics of the forecast need to be defined. Short-range forecasts. nowcasting and out to 3 days are expressed in terms of absolute values; for example, expected temperatures rather than trends or departures from normal. Similarly, winds, humidity, and precipitation are quantitatively expressed, albeit as a range of each variable, and for specific locations. Forecasts for the 6 to 10 day period or out to 30 days, however, are expressed as trends or change on the 10-day period, and are expressed as probable (with probability bounds) departures from normal for 30-day forecast periods. Postprocessing of forecasts for periods of 6 to 10 days and out to 30 days will be expressed as statistical descriptors.

Fire-danger rating is an example of nonmeteorological postprocessing. Weather forecasts are used to calculate forecast fire danger indicies and to establish forecast manning and action class levels for the next day. Medium-range forecasts also have demonstrated postprocessing use. For example, air pollution episodes are forecast routinely for Western Europe, and forecasts of ice pack movements are used to pre-position icebreakers in the Baltic Sea. There has been limited success in using extended-range forecasts to pre-position fire crews and equipment in the United States. Current research activities focus on both improving these extended-range forecast applications and in improving the spatial resolution of medium-range forecasts. The goal is to provide information for decision analysis procedures in pre-positioning crews and equipment for both wildfire and prescribed fire opportunities.

Information content of forecasts as used here is in two parts. First is the technically or statistically significant content of information exceeding that contained in climatology. Skill scores have been designed to measure the accuracy of forecasts. Medium- and extended-range forecasts show meteorological skill in that information is contained in the forecast. How useful is that information? Does the forecast contain sufficient information to influence a fire manager's decision? A second measure of information content is the economic value of information (Brown and Murphy 1987). Specifically, can weather or fire severity forecasts actually show both skill and economic value?

Quantitative analysis of the forecasts through modeling of the decision process for pre-positioning crews and equipment for wildfire and even for prescribed fire is likely to be a major postprocessing activity in the future.

FUTURE USE OF WEATHER INFORMATION

Having assessed the current state of observations, forecasting, and postprocessing of weather, and having estimated the changes taking place, I have covered the first two steps in forecasting. Now I will apply these changes to the described initial state and forecast weather forecasting.

Techniques to design specialized weather station networks will be available and will be able to address multiple resource needs, e.g., fire, air quality, and water. We will see significant improvement in the weather observations at the surface. A corresponding upper air wind observation network, particularly in the mountainous West, will be deployed much more slowly. As a result, the assessment of the initial state of the weather will still be imperfect. The cost of implementing a high spatial and temporal resolution observational system will limit use of the technology.

Weather forecasting on the nowcast of high spatial resolution and short-time scales will become operational in only geographic areas with very high fire risk and potential damage, such as the urban/wildland interface. Use of this technology still will be limited to nuclear and chemical facilities with only minor efforts in fire management of the urban-wildland interface. Again, economics will dictate the rate of implementation of these technologies.

Short-range (out to 3 days) forecasting will continue to show steady, albeit slow, improvements in accuracy. The notable exception here will be in spot forecasts, which are based on the covariance matrices of spatial and temporal variability. These forecasts will provide more accurate information to fire management for initial attack. Medium-range forecasts have achieved operational acceptability and extended-range forecasts will soon reach that level for management decisions. These forecasts are and will be presented in a probability format. Fire management use of these forecasts will depend to a large extent on management capabilities to accept probability distributions as the forecast rather than a single value.

These probability distribution forecasts are actually better forecasts for decisions based on medium- and extended-ranges. Uncertainty in timing of a particular weather event, or the spatial position and distribution of that event are better expressed as probability distributions. These probability distributions will be the weather forecasts of the future.

Finally, I turn to postprocessing of weather forecasts. This is where fire management will see the greatest gain in meteorological support. Medium- and extended-range forecasts will be processed with a variety of fire danger and drought measures to forecast fire severity. These forecasts will be used to pre-position crews and equipment on both national and regional scales.

REFERENCES

Brown and Murphy. 1987. Value of weather forecasting in making wildfire suppression mobilization decisions. Corvallis: Dept. of Atmos. Sci., Oregon State Univ. (in preparation).

Browning, K. A. 1982. Nowcasting. London: Academic Press; 256 p.

Byram, George M. 1959. Combustion of forest fuels. In: Davis, Kenneth P. ed. Forest fire control and use. New York: McGraw Hill Book Co., Inc.

Chadwick, Russell B.; Hassell, Norman. 1987. Profiles: the next generation surface-based atmospheric sounding system. Third International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology. Boston, MA: Amer. Meteorol. Soc.; 15-21.

Deeming, John E.; Lancaster, James W.; Fosberg, Michael A.; Furman, William R.; Schroeder, Mark J. 1972. National Fire-Danger Rating. Res. Paper RM-84. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 165 p.

Dell'Osso, L. 1984. High resolution experiments with the ECMWF model: a case study. Monthly Weather Review 112: 1853-1883.

Durham, Anthony F.; Wilk, K. E. 1987. NEXTRAD--the nation's next generation weather radar. Third International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology. Boston, MA: Amer. Meteorol. Soc.; 12-14.

Folland, C. K.; Woodcock, A. 1986. Experimental monthly long-range forecasts for the United Kingdom. Part 1. Description of the forecast system. The Meteorological Magazine 115: 301-318.

Fosberg, Michael A. 1978. Weather in fire management: The fire weather index. In: Conference on Sierra Nevada Meteorology. 1978 June 19-21; Lake Tahoe, CA. Boston. MA: Amer. Meteorol. Soc.; 1-5.

Fosberg, Michael A. 1984. A diagnostic three-dimensional mass and momentum conserving wind model for complex terrain. Third Conference on Mountain Meteorology. Boston, MA: Amer. Meteorol. Soc.; 13-16.

Fosberg, Michael A. 1985. Modeling smoke plume patterns in drainage flow. Eighth Conference on Fire and Forest Meteorology, Washington, DC. Soc. Amer. Foresters; 157-160.

Fosberg, Michael A.; Fujioka. Francis M.; 1987. Medium- and extended-range fire severity forecasting: A national research plan. Ninth Conference on Fire and Forest Meteorol., Amer. Meteorol. Soc., (in press).

Fosberg, Michael A.; McElroy, James L.; Wakimoto, Roger M. 1987. Experimental and numerical study of transition from an air quality episode to a Catalina eddy in the Los Angeles Basin. Manuscript in preparation.

Fujioka, Francis M. 1986. A method for designing a fire weather network. J. Atmos. and Ocean. Tech. 3: 564-570.

Gilchrist, A. 1986. Long-range forecasting. Quart. J. Roy. Meteorol. Soc. 112: 567-592.

Jacobson, S. E.; Brucker, J. 1985. Final report on the development of nonlinear optimization procedures for meteorological network design. Los Angeles: Dept. of Elec. Eng.. Univ. of California; 76 p.

Klein, William H. 1978. Model output statistics in the Western United States. Conference on Sierra Nevada Meteorology. Boston, MA: Amer. Meteorol. Soc.; 11-18.

McCutchan, Morris H.; Schroeder, Mark J. 1973. Classification of meteorological patterns in southern California by discriminant analysis. J. Appl. Meteorol. 12: 571-577.

McGinley, J. A. 1986. Vorticity budgets for alpine cyclogenesis with and without the forcing of terrain scientific results of the Alpine experiment. In: GARP Publication Series No. 27, Vol. 1. Geneva: World Meteorol. Org.; 265-280

Ross, D. G.; Smith. I. 1985. Diagnostic windfield modeling--development and validation centre for applied mathematical modeling. Caulfield, Victoria: Chisholm Institute of Technology; 62 p.

Rothermel, R. C. 1972. A mathematical model for fire spread predictions in wildland fuels. Res. Paper INT-115. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service. U.S. Department of Agriculture; 40 p.

Schroeder, Mark J.; Glovinsky, M.; Hendricks, V.; and others. 1964. Synoptic weather types associated with critical fire weather. Berkeley. CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 492 p.

Vance, Dale L.: Krider, Philip E. 1978. Lightning detection systems for fire management. Fifth Conference on Fire and Forest Meteorol. Boston, MA: Amer. Meteorol. Soc.; 68-70.

Wolfson, Marilyn M. 1987. The flows automatic weather station network. Sixth Symposium, Meteorological Observations and Instrumentation. Boston, MA: Amer. Meteorol. Soc.; 294-299.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Forest Fire Research--Hindsight and Foresight[1]

C. E. Van Wagner[2]

Abstract: The evolution of Forest fire research in Canada first is examined through the works of Wright and Beall, at the Petawawa National Forestry Institute in Ontario, then some lessons are drawn from the past that ought to bear on the future. Some opinions are delivered on the future course of research in fire danger rating, prescribed fire and the impacts of fire on the forest economy.

The title of this presentation is based on the principle that the past is the key to the future. If not absolutely true all of the time, this principle works well enough that "to look backward as well as forward before leaping ahead" is always good advice in the world of research. Scientific investigation of forest fire is over 60 years old in North America, and already many older references have probably been abandoned or lost; new recruits steeped in computer technology have a harder and harder time evaluating what has gone before, and can easily lose confidence in any bit of work older than a decade or so.

But, when referring to the past why stop at 60 years? Familiarity with fire must be as old as the human race, and the taming of fire was possibly the first step in the development of human culture. Discovery of the basic principles of fire behavior must have followed quickly, whether around the campfire or cut in the landscape. Namely,

(1) fire ignites and spreads more quickly in dry fuel than in wet,

(2) small pieces ignite and burn easily while large pieces hold the fire longer, and

(3) there is an optimum spacing of pieces at which the fire burns best. And, just as modern fire research programs maintain a proper balance between the physical and ecological faces of fire, so the practical uses of an area as it redeveloped after fire were certainly learned, no doubt even before the taming of fire itself. For example, while the new stand of trees grew, the obvious concerns were

(1) the ready supply of dry firewood on the stump,

(2) how many years later to look for berry crops, and

(3) what kinds of animals returned first. What we call "fire science" is, in fact, the codification and quantification of a fair amount of basic knowledge known to the human race for a very long time indeed. Fire was also obviously two-faced, at times either an enemy or friend; we are still learning how to tell the difference.

LOOKING BACK--THE WORK OF WRIGHT AND BEALL

Closer to home in time and place, the father of forest fire research in Canada was James G. Wright, who proposed a program to develop ways of measuring fire hazard in 1925. Field work began during the summers at the Petawawa Forest

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Experiment Station. and by 1929 was in full swing (Wright 1932). Herbert W. Beall joined Wright as a student in 1928 and between them they held the fire research stage in Canada with occasional help for about 20 years.

Their principal accomplishment was the Wright System of fire-hazard rating (Wright 1933, Beall 1950a), which to this day forms the basis of the Canadian Forest Fire Weather Index System. The original Tracer Index for pine litter (Wright 1937) has evolved into the Fine Fuel Moisture Code, and the current Fire Weather Index has direct physical and mathematical links with the old Fire-Hazard Index.

In fact, the research of Wright and Beall covered such a wide range of subject matter that it is hard to find an important aspect of forest fire science on which they left no mark. Here is a partial list (only a few references out of many possible are noted):

In fuel moisture research,

--sorption isotherms for fine fuels, showing the hysteresis between the drying and wetting parts of the cycle,

--development of the tray method of measuring change in fuel moisture content from day to day,

--clear evidence that moisture content decreases in proportion to current content (the negative exponential drying process, although they did not name it so), and

--joint effects of rain amount and duration in raising the moisture content of forest litter, dependent further on the initial content before rain.

In fire danger rating,

--development of the Wright System, based on the link between the behavior of standard 2-minute test fires and fuel-moisture-plus-wind,

--a method for varying fire danger around the clock (Beall 1934),

--evaluation of the accuracy of the danger index in terms of distance from the weather station (Beall 1950b), and

--the variation of fire hazard with the seasons (Wright and Beall 1934). In various other aspects of fire,

--analysis of long-term fire statistics (Wright 1940a), with the suggestion, still intriguing, of a periodic pattern in annual burned area that just happens to match the sun-spot cycle (Wright 1940b),

--a major scheme for acceptable maximum burned area for forest types across Canada, based on productivity, fire risk, flammability, current detection and attack potential, and harvest value (Beall 1949),

--studies on fire control equipment and gear such as pumps, hose, lookout towers (Wright 1942) (seen area, lightning protection, binoculars), fire-fighting chemicals, and so on.

During all this time, Wright and Beall paid careful attention to the similar work begun about a decade earlier in the United States. A review of the meteorological aspects of fire-hazard research (Wright and Beall 1945) lists a host of semi-forgotten references with quotations that demonstrate the considerable age of most of our basic principles. Beall (1947) alludes to certain differences in approach between the American and Canadian schools of fire research that have continued down to the present.

LESSONS FROM THE PAST

The first lesson we have learned from the remarkable output of Wright and Beall is to study carefully the old fire research results and, if possible, to adapt them rather than to start again from scratch every time a problem arises. The second lesson is that the same practical research output may require continual redevelopment to keep one jump ahead of advances in modern technology. Fire danger rating in Canada is a good example; its evolution can be followed through at least six stages:

First, the Wright System began life as a hazard index based on empirical field data analyzed by complex graphical correlation methods and worked into a set of tables. It depended on considerable weather information.

Second, as its use expanded, the demand to "keep it simple" led to reduction in the weather requirements to a bare minimum of four elements (temperature, humidity, wind, rain) taken once daily at solar noon. This easy-to-use version then spread throughout Canada.

Third, in response to pressure for more information than the simplified system could provide, physics and laboratory results plus more field experiments were added to the data base, and the whole redeveloped into a set of standard equations. The Fire Weather Index (FWI) System was born, equally adapted to computer processing as to manual table entry.

Fourth, as computer capacity increased at a remarkable rate, the way opened to the development of comprehensive computerized fire management systems, incorporating and using the FWI System as a basis for any management operation needing an estimate of ignition potential or fire behavior.

Fifth, the now obvious need for absolute rather than relative values has led to a set of spread-rate equations based on empirical field data, and using components of the FWI System. A companion set of fuel-consumption (and hence intensity) equations is in process. Fire danger rating thus blends into fire behavior prediction, and management system output can in turn take a more quantitative form.

Sixth, as computer capacity expands in almost open-ended fashion, expert systems and artificial intelligence have entered the scene. Who knows what wonders will follow?

Obviously the story has not ended, and presumably never will.

LOOKING AHEAD--THE MAJOR ISSUES IN CANADA

What then of the future? Let us look in turn at several aspects of the fire research business, asking not just whether a potential goal is possible, but also whether it is practically feasible and worthwhile as well.

Take fire danger rating as the first case. The weakest link in the present chain is clearly the weather input. The entire structure of standard fire danger rating and fire behavior prediction in Canada rests at present upon the slim basis of four elements read once daily at noon, one instantaneous sample of a 24-hr continuum. Furthermore, the data are accumulated at a series of single stations, not necessarily spaced to best advantage. I suppose that means of weather interpolation throughout time and space will be more and more in demand. There is now no technological limitation on more frequent automatic weather readings from anywhere, say once per hour. Potential methods for interpolating temperature, humidity, and wind exist or are under development, while radar holds promise for areal rainfall measurement. In serious fire situations or prescribed fire operations, this whole apparatus can be brought to bear, and methods of computing fire danger at any time interval around the clock are well in hand. As remote weather measurement becomes more and more sophisticated, let us even contemplate continuous computation of fire danger at the site from mathematical functions of weather at the differential level, to be called upon at will. All this stream of information is grist for the mill of fire growth modelling.

What about direct means of determining fuel moisture? Exposure of analogs or quick field methods will always have their advocates; however, the former need careful maintenance and the latter depends critically on sampling intensity. Moreover, neither lends itself to prediction from forecasted weather. For this reason alone, as long as we can do reasonably well with weather-based models, I doubt that direct measurement will ever replace weather-based moisture schemes in Canada.

Take fire behavior prediction as the second case. We, in Canada, are fairly well committed to empirical means, namely linking observed real fire behavior to components of our Fire Weather Index System. At any time in the future, a physical model that takes full account of vertical gradients in fuel moisture content, bulk density, and size variation may become available. Even though it may prove superior to empirical means, the problem of acquiring all the necessary data to feed such a model looms as the stumbling block. It is one thing to measure carefully every aspect of fuel quantity and arrangement for an experimental fire, but quite another to assemble and digitize such data for extensive areas. For example, all the skills of remote sensing cannot yet match the simple mensurational data on tree species, diameter, height and stocking produced by a simple surface cruise. In other words, to replace a well-established empirical system for predicting fire behavior, not only will an adequate comprehensive model be required, but the means of acquiring the necessary data on a large scale must be available as well.

There is one other intriguing aspect of fire behavior that will require more and more attention in Canada. This is the large-scale mass-ignited prescribed fire. The first question concerns the ignition pattern: how best to arrange the points and lines of fire, and how to judge the length of time needed to burn out between lines. The second question concerns the convection column: what cause-and-effect link, if any, exists between surface combustion and the column, and what will be the pattern of smoke dispersal? The third question concerns fire whirls: the circumstances causing them, and whether they pose any threat to the surrounding area. For purposes of economy, the larger the burn the better. Thus, single prescribed fires may encompass as much as 2000 ha, and the practical limit of this upward area trend is in question. For both safety and efficiency, better understanding of their behavior is highly desirable.

Take forest development after fire as the next case. Two great practical issues promise heavy debate during the next decades. One is the question whether prescribed fire may have negative effects on tree growth over the entire subsequent rotation. In Canada this issue is warmest in British Columbia, especially on the heavy-timbered West Coast. The important point in my opinion is that the final judgment be deferred until the long-term evidence is in hand. The nutrient dynamics of any site will certainly be rearranged by traumatic events like clear-cutting or fire, or both. But most forested areas in Canada have burned, say, 20 to 100 times in the past 5000 years. and the proper basis for the study of nutrient effects is clearly the entire cycle from one fire to the next. The other major issue is how to come to terms with fire in the national and other large natural parks. After decades of fire suppression the age-class distribution in many large parks is bell-shaped and overmature. Parks Canada particularly, has produced an enlightened new policy in the past few years; it is now the operational problem that faces us. The challenge will be to maintain a philosophy based on the logical principles established by research through all the growing pains of developing the means or reintroducing fire into fire-dependent ecosystems. Whether this can ultimately be done adequately is simply not certain.

Take the impact of forest fire on the forest industry and economy as the next case. In spite of the considerable literature on the economic issue I cannot regard the matter as settled, in Canada at least. It is only several years since the first analyses of how fire affects the timber supply have appeared. Here the logic is inexorable; salvage aside, the annual harvest comes from the whole forest, not the burned area. Conversely, the traditional basis for evaluating economic impact has been the burned area only. The obvious question is, why not analyze for economic impact as well on the whole-forest basis? The principle might be called "maximized net return" rather than "least cost-plus-loss." I believe that the stage is set for a proper debate on this issue in Canada. Throughout the argument run threads of various familiar issues such as "forest rent vs. soil rent," the "annual allowable cut effect," and whether forest industry should aim to maximize wood production or direct economic return. The outcome will decide whether fire management is an integral part of forest management as a whole or rather just a self-contained entity of itself. The driving force will come as more and more forestry people desire the rationalization of exactly what fire does to the national forest economy.

An incidental result of acceptable rational analysis of fire's impact will be to place some economic limit on the benefits of fire management. Whether researchers should worry about this depends on one's point of view. My own is that because forest fire is an integral part of the forest's environment, scientific expertise in it will always be in demand. Our function should be, I believe, to shed rational light on all aspects of fire management in the larger sense. The actual reduction of fire losses is the responsibility of the fire management agencies, and it would hardly be fair to ask the researchers to stand or fall on the success or failure of this enterprise.

Take possible trends in annual weather and climate as the last case. Not only is the weather the principal driving force behind the phenomenon we study, but the success of fire management depends on how well we adapt to the annual variation in weather from year to year. The story of the past two decades in Canada is instructive. As of the late 1960's, the running 10-yr national average annual burned area stood at about 900,000 ha following an almost continuous downward trend of four decades. Between 1970 and 1983 all but three fire seasons registered over 1 million ha including, back to back, the two highest values on record, 4.8 and 5.4 million ha in 1980 and 1981. The running average reached 2 million ha; it has fallen somewhat since, but still stands as high as at any time in the period of record.

There is nothing in this story for the fire management agencies to be ashamed of. Advances in fire control technology notwithstanding, the overwhelming factor was simply, year after year, the weather. But why this concentration of severe fire seasons such as were seen only occasionally during the previous several decades? This is a question for the climatologists. Perhaps this episode is in fact a portent of the climate change that will gradually occur as the concentration of carbon dioxide in the air increases. There is more and more agreement that global temperature will indeed rise, and that the increase will be felt most in the high latitudes. If, as further expected, higher temperatures would be accompanied by an increase in the ratio of evapotranspiration to precipitation, the result is a recipe for more severe fire weather. As soon as rough quantitative estimates of the net change become available, they can be modelled into a picture of the fire weather of the future. As interest in this subject increases, one can expect more and attempts to predict the nature of the forthcoming fire climate, and to plan some response. The outcome could range all the way from an increase in seasonal severity well within the present range to a challenge so profound as to shake fire management to its foundation. By the time the year 2000 dawns, we will, I have no doubt, a much better sense of this issue than at present.

CONCLUSIONS

Having run out of major fire research subjects on which to comment, let me now reaffirm my belief in the basic principles of science that have brought us thus far in the past six decades: certainly the deductive rather than the inductive strategy, and a balanced respect for both the empirical and theoretical approaches. New fire control technology may come on stream at a bewildering rate, and the computer revolution will lead who knows where. The development of expert systems and artificial intelligence will certainly run its course and their products will find their place. Throughout all this excitement, a firm scientific conclusion based on a well-conceived field or lab results backed up by the appropriate physics and biology will, I believe, continue to be the basis of every real advance.

Beyond science, I believe also that because fire has such deep and ancient roots in human history and culture, social and political reactions as well as objective reality will always affect strongly what is done about fire in our forest. Our part in the future of fire management will provide the most rigorous, objective view of the phenomenon itself, its role in nature, its impact on the economy, and the practical means of controlling it as "enemy" while utilizing it as "friend." And, to echo my opening statement, we are well advised to look backward first every time we contemplate a leap forward.

REFERENCES

Beall, H.W. 1934. Diurnal and season fluctuation of fire-hazard in pine forest. For. Chron. 10: 209-225.

Beall, H.W. 1947. Research in the measurement of forest fire danger. Paper presented at Fifth Brit. Emp. For. Conf. Reprinted as Inform. Rep. FF-X-8, Forest Fire Res. Inst., Can. For. Serv., 1967. Ottawa. Ontario; 20 p.

Beall, H.W. 1949. An outline of forest fire protection standards. For. Chron. 25: 82-106.

Beall, H.W. 1950a. Forest fire danger tables (provisional). Can. Dep. Resour. and Dev., Forest Fire Res. Note No. 12 (2d ed.). Ottawa, Ontario; 73 p.

Beall, H.W. 1950b. Forest fires and the Danger Index in New Brunswick. For. Chron. 26: 99-114.

Wright, J.G. 1932. Forest-fire hazard research as developed and conducted at the Petawawa Forest Experiment Station. Can. Dep. Interior, Forest Serv. Forst-Fire Haz. Pap. No. 2. Reprinted as Inform. Rep. FF-X-5, Forest Fire Res. Inst., Can. For. Serv. 1967. Ottawa, Ontario; 63 p.

Wright, J.G, 1933. Forest-fire hazard tables for mixed red and white pineforests. Can. Dep. Interior, Forest Service., Forest-Fire Haz. Pap. No. 3 Ottawa, Ontario; 18 p.

Wright, J.G. 1937. Preliminary improved Fire Hazard Index Tables for pine forests at Petawawa Forest Experiment Station. Can. Dep. Mines and Resour., Dom. Forest Service. Ottawa. Ontario; 42 p.

Wright, J.G. 1940a. Long-term trends in forest-fire statistics in Canada. For. Chron. 16: 239-244

Wright, J.G. 1940b. Sun spots and forest fires in New Brunswick. For. Chron. 16: 231-238.

Wright, J.G. 1942. A lightening protection system for forest lookout structures. Can. Dep. Mines and Res., Dom. Forest Serv..

Forest-Fire Res. Note No. 11. Ottawa, Ontario; 16 p.
Wright, J.G.; Beall, H.W. 1934. Seasonal vegetation and forest fire hazard. Pulp and Paper Mag. of Can. April: 259-261.
Wright, J.G.; Beall, H.W. 1945. The application of meteorology to forest fire protection. Imp. For. Bur., Oxford. Tech. Comm. No. 4. Reprinted as Inform. Rep. FF-X-11, Forest Fires Res. Inst.. Can. For. Serv. Ottawa. Ontario; 39 p.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Assessing Subjective Preferences for Future Fire Research[1]

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Abstract: Methods are described for making comparative valuations of future fire (or any other) research efforts when the benefits that result from some of the efforts cannot be described in dollars. The process helps research managers and scientists set priorities by using the values and beliefs of skilled fire specialists. The objective is to insure coherent decisions consistent with stated values. The process has application in decision problems faced by all executives and has been tested in a variety of forestry applications.

In terms of forestry and fire control, the year 2000 has already arrived. The near future is committed by today's decisions about how long-range research programs are proposed and how constraints are imposed. Just as forest management plans shape the size and timing of harvesting operations far into the future, so the networks of research paths, priorities, and long-term investments in fire research and allocation of resources among research areas determine the fire prevention and management technology of the early 21st century.

This paper describes methods to set priorities among research, development, and application efforts by using subjectively derived benefit scores and projected costs. The methods have been used several times in a variety of research priority evaluations (Davis and Shafer 1984, Shafer and others 1977, USDA Forest Service 1981). For example, the technique for determining benefit scores was used in the Forest Service's program analysis for the 1985 Resource Planning Act (RPA) and was also tested in the pilot study described in this paper. However, as far as I know, the methods have not been previously reported in the fire related literature. In the example described, these techniques are used to set priorities on several possible research and development efforts for dealing with the fire problem at the wildland/urban interface. The methods are a set of several possible techniques to analyze attribute values subjectively.

Although the loss of structures to wildfire is not new, the potential for fire loss is increasing dramatically as more people build their homes and live in proximity to flammable forests and woodlands. So rapid has been the build-up that, in some parts of this country, homes and other property exposed to wildland fire have increased fourfold during the past 5 years.

The problem is national in scope. Fire protection agencies, homeowners, builders, developers, and local planning agencies all share responsibility in finding ways to reduce this existing and potential loss of property and life (Davis and Marker 1987). Solutions range from effective application of what we already know, such as limitations on flammable building materials, to the need for new research in the many areas where our knowledge is limited.

THE PROBLEM OF SETTING PRIORITIES

Usually, there are never enough dollars or other resources to go around. Inevitably.

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research (and fire) managers must set priorities on projects or efforts that cannot be evaluated through conventional analysis. I want to emphasize that subjective techniques are not a substitute for measurement when it is possible. But, for example, fire commissioners may have to choose between alternate fire station locations, or a forest fire protection officer may need to find a balance between fire suppression and prevention when developing an annual budget. In such cases, precise measurement may not be obtainable, yet expert opinion is. In the pilot study discussed in this paper, the problem was where to concentrate scarce research and management dollars.

A DESIGN FOR SETTING PRIORITIES

The design described does not make decisions or portend what to decide. Rather, it helps managers to decide what the priorities should be by using, and making explicit, a consensus of values and beliefs. The objective is to ensure coherent decisions consistent with stated values (Kahn and others 1964, Richards and Greenlaw 1972).

The design involves seven steps:

1. List the items to be evaluated. The list should include all of the options available to the decision-maker, such as a list of the major equipment that might be purchased over the next few years.
2. Select a panel of objective evaluators who are expert on the subject.
3. Survey the panel to evaluate the items in terms of their overall benefits.
4. Compute benefit scores.
5. Estimate the costs.
6. Compare initial benefit scores and costs.
7. Adjust benefit scores to reflect management's values and beliefs.

Each step is described below, using data obtained in a pilot survey of fire managers and foresters familiar with the wildland/urban interface problem.

List the Items

In developing a problem analysis to define research needed on the wildland/urban fire problem, I needed to arrange the following nine research efforts--A through I--in order of their priority, based on each effort's overall benefits and estimated costs as perceived by fire experts:

A--Fundamental or basic knowledge about the physics of spotting and crowning in the urban/wildland interface and the development of fire behavior prediction models.

B--Effective ways to educate property owners, land developers, insurance carriers, and local planners about the problem.

C--Knowledge about relationships of building design, materials, and landscaping to fire hazard and behavior.

D--Aids for planning and budgeting, and training fire control personnel for increased involvement in both structural fire protection and wildland fire control. (How can local, state, and federal fire control forces be used more efficiently?)

E--Methods and systems to economically and efficiently measure and evaluate the risk and hazard over broad geographical areas.

F--Strategies to manage fuel hazard in the urban/wildland area such as mechanical clearing of vegetation, application of herbicides, and prescribed use of fire.

G--Methods to incorporate social, political, regulatory, and other factors in an overall economic understanding of fire protection investments. Fire protection investments are complex and considered "non-linear" by economists, who frequently don't get as much return on an investment at all investment levels. Research would include determining who pays. (Are insurance premiums and disaster loans inadvertently subsidizing high risk construction?)

H--Information on the selection of low growing or fire resistant vegetation for landscaping or greenbelt construction including maintenance and management strategies. (Who pays the cost?)

I--Information on the feasibility, costs. and benefits of engineered hazard reduction systems such as sprinklers (possibly using sewage effluent), road system design, and the possible use of flame or heat barriers and deflectors in critical areas.

We used a volunteer panel and consequently tried to make the task descriptions as succinct as possible in a short paragraph of text. The degree of generality or specificity in the item description was kept as uniform or as parallel as possible. This is essential in a full scale study, and a great deal of care must be taken in preparing the text. Obtaining professional editorial or copywriting help is probably essential.

An important limitation on the ratio-scaling method described in this paper is the practical limit on how many items can be compared. The equation is

$$f = \frac{n(n-1)}{2}$$

where "f" is the number of paired comparisons and "n" is the number of things to be compared. In this wildland/urban interface study, "n" equaled 9; consequently, there were 36 comparisons--about as many as one can expect from a panel of busy people.

Select a Panel

The second step is to select a panel of knowledgeable people to judge the importance of the items to be evaluated. The number to include in the panel depends on the variation in the subjects to be considered. There is always the question about how much time an expert panelist will spend in studying and understanding the issues to be compared. There is a tradeoff between a small group of "committed" panelists and a larger group, who can bring a wide range of insight to the analysis but who may not wish to spend much time on it.

The panel consisted mostly of foresters and fire managers attending the California-Nevada-Hawaii Fire Council meeting in Reno, Nevada, in fall 1986. The principle subject of the meeting was the wildland/urban interface fire problem and all panelists had 2 days of discussion about the subject prior to the survey.

Conduct a Survey

At the end of the conference, 75 participants were given a 10-page "ratio scaling" questionnaire to take home and fill out at their convenience. Forty-five returned them. The technique required each participant to divide 100 points according to personal preference over each of the 36 possible pairs of the nine research efforts being evaluated. In each pair, the 100 points were divided into a proportion of the greater to the lesser effort. For example, a participant might assign 60 points to effort A and 40 points to effort B if he or she believed that A was in the ratio of 60 to 40 or 3 to 2, with B. The average participant took about half an hour to complete the questionnaire.

Compute Benefit Scores

Table 1 shows the average number of points from 100 assigned to the research efforts listed from A to I across the top of the table in their comparisons with the efforts listed down the left side of the table (Torgerson 1958, Edwards 1957). For example, "Education of property owners, land developers, etc." (effort B) received an average of 51.98 points when it was compared with "Methods to incorporate social and other factors" (effort G). Methods to incorporate social and other factors, on the other hand, received 100 minus 51.98 or an average of 48.02 points in the same comparison.

Table 1--Average points assigned in comparative judgement (While the methodology does not yield accuracy to the second decimal place, serious rounding errors result if decimal places are reduced.)

Research effort	A	B	C	D	E	F	G	H	I
A	----	71.86	64.30	59.65	49.88	67.21	64.77	61.40	52.67
B	28.14	----	43.49	42.21	35.70	43.84	48.02	41.40	33.37
C	35.70	56.51	----	48.02	43.26	49.53	55.93	50.47	36.86
D	40.35	57.79	51.98	----	41.98	53.84	55.23	51.86	38.02
E	50.12	64.30	56.74	58.02	----	59.77	61.40	57.21	47.79
F	32.79	56.16	50.47	46.16	40.23	----	55.23	48.72	37.91
G	35.230	51.98	44.07	44.77	38.60	44.77	----	41.28	35.58
H	38.60	58.60	49.53	48.14	42.79	51.28	58.72	----	41.28
I	47.33	66.63	63.14	61.98	52.21	62.09	64.42	58.72	----

Table 2 shows the ratio of points between efforts B and G (i.e., 51.98/48.02=1.08) and has been rearranged so that the efforts are listed across the top in order of importance as judged by the number of points they received. Thus "Effective ways to educate property owners, land developers, etc." (B) received the most points and "Fundamental knowledge about the physics of crowning and spotting" (A), the least.

The next to the bottom row in table 2 shows the sums of the ratios in each of the columns (i.e., 13.80 is the sum of the ratios in the first column). If these sums are in turn summed across the next to bottom row the total amounts to 86.04 points for all of the research efforts.

In the last row of table 2, the benefit values have been normalized so that they sum to 1000 (i.e., the normalized value for B is 13.80/86.04 x 1000 = 160). These normalized benefit values are used in the tables and figures that follow.

The following overall results were obtained:

Research Effort	Score
B--Education of property owners, developers, etc.	160
G--Methods to incorporate social and other factors.	141
C--Knowledge about building design and materials.	122
F--Strategies to manage fuel hazard.	118
H--Low growing and fire resistant vegetation.	114
D--Aids for budgeting and training fire crews.	113
E--Methods to evaluate risk and hazard.	83
I--Information on engineered hazard reduction systems.	77
A--Basic knowledge about spotting and crowning.	72

As frequently happens, this pilot study raised more questions than it answered:

Would the scores have been the same in other parts of the nation?

Would the scores have been the same if the questionnaire had been taken prior to the meeting--were the judges unduly influenced by the presentations?

How would homeowners who had never been involved with forestry or fire departments have responded?

What would have been the scores of a statistically sufficient group of builders, planners, and insurance carriers?

Table 2--Example of how benefit scores were calculated for nine research efforts showing ratios of points assigned in comparative judgment (Judgement scores are reorganized in decreasing order). Diagonal cells are all 1.00 (X/X=1.00). Normalized scores sum to 1000.

Research effort	B	G	C	F	H	D	E	I	A
B	1.00	0.92	0.77	0.78	0.71	0.73	0.56	0.50	0.39
G	1.08	1.00	0.79	0.81	0.70	0.81	0.63	0.55	0.54
C	1.30	1.27	1.00	0.98	1.02	0.92	0.76	0.58	0.56
F	1.28	1.23	1.02	1.00	0.95	0.86	0.67	0.61	0.49
H	1.42	1.42	0.98	1.05	1.00	0.93	0.75	0.70	0.63
D	1.37	1.23	1.08.	1.17	1.08	1.00	0.72	0.61	0.68
E	1.80	1.59	1.31	1.49	1.34	1.38	1.00	0.92	1.00
I	2.00	1.61	1.71	1.64	1.42	1.63	1.09	1.00	0.90
A	2.55	1.84	1.80	2.05	1.59	1.48	1.00	1.11	1.00
Sum	13.80	12.11	10.46	10.17	9.81	9.74	7.18	6.58	6.19
Normal score	160	141	122	118	114	113	83	77	72

Estimate the Costs

Perceived benefits from research are only half of what is needed to set priorities (Sinden and Worrell 1979). One also needs to know what the research might cost. In the following example, I estimated costs covering a 5-year period as part of my preparation of a research problem analysis. In general practice, experienced persons should estimate the cost of the effort without being influenced by benefit scores. For example, in the RPA analysis, separate groups were used to determine costs and benefits.

The cost "stream" over the life of the effort is discounted to present worth--the money needed today to fund the research over its life span. The rate of interest should be based on current economic trends. Only efforts with similar time frames should be compared. An effort that will be quickly terminated, or one for which funding will be delayed, usually should not be compared with the others.

Compare Initial Benefit Scores and Costs

Each effort is then ranked and plotted according to benefit scores to form a benefit-only criterion curve (table 3, fig. 1). That is, the research effort with the highest benefit score (in this case B) is plotted first, against its cost. The research effort with the next highest benefit score (G) is plotted second, in a cumulative manner, etc., until all efforts are arranged along a curve (fig. 1).

Research efforts are also plotted by a benefit-cost criterion (benefit score/cost). In this case, C is plotted first because it has the the largest benefit-cost value (table 3). G is next, etc. (fig. 1). The two resulting curves provide data that can be used along with other considerations for making decisions under various cost constraints, about program content and the priorities within those programs. As figure 1 shows, the benefit-cost criterion curve always provides the same or more benefits for a fixed research investment. For example, if a

Table 3--Initial and final result, after fine tuning the benefit scores, of the nine research efforts

Research Effort	Initial Results			Final Results	
	Discounted Cost (Thousands)	Initial Benefit Score	Initial Benefit/ Cost Ratio	Final Benefit Score	Final Benefit/ Cost Ratio
B. Educate					
B. Educate Owners Etc.	200	160	0.80	217	1.09
G. Social and Political	150	141	0.94	117	0.78
C. Building Design	100	122	1.22	101	1.01
F. Fuel Hazard	500	118	0.24	187	0.37
H. Fire Resist. Vegetation	350	114	0.33	94	0.27
D. Planning Budgeting	200	113	0.57	93	0.47
E. Measure and Evaluate	300	83	0.28	68	0.23
I. Costs and Benefits	450	77	0.17	64	0.14
A. Spotting and Crowning	750	72	0.10	59	0.08
Totals	3000	1000		1000	

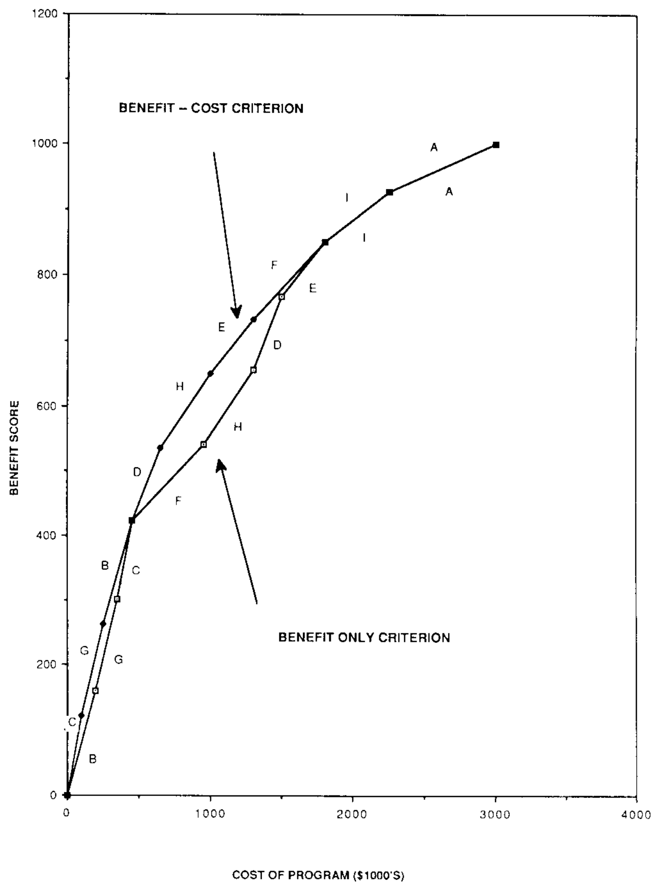

Figure 1--Initial comparison of benefit cost vs. benefit only criterion.

research program budget for urban/wildland research is set at $1,000,000 (discounted cost stream over 5 years), a program that contains research efforts C. G. B, D and part of H--with a total benefit score of 650--might be preferred over a program with research efforts B, G. C. and F--with a total benefit score of only 560 (fig. 1)--even though B was the highest priority research when only benefits were considered.

Adjust Benefit Scores For Management

The primary advantage of this method up to this point is that it provides an organizing framework for analyzing complex situations. However, since management is responsible for content and success of its research program, final decisions on content and benefits of that program is their responsibility. Management may wish to adjust initial results based on social, political, economic, or scientific information that may not have been evident or important to panel members.

The system permits a systematic method whereby management, if it wishes, can examine and may change benefit scores (and thus the location) of efforts along the benefit-cost criterion curve (Armstrong 1979). The only constraint is that regardless of the number of changes made, the sum of the benefit scores must equal 1000. For example, if management wants to increase the benefit scores of one effort, it must reduce the value of another or others, by an equal amount. Shafer and I have used the following adjustment process several times and believe that it should be adaptable to many research situations:

Management compares the program containing efforts C and G on the benefit-cost criterion curve with B on the benefit-only criterion curve. B costs almost as much as C and G together, but C and G have about 1 1/2 times the benefit score value as B. However, management may believe that B is more important than C and G, regardless of what the data suggests (table 3). So, B's benefit score is adjusted--let us say to 263 to make it equal in value to C and G. The reason for the change is documented, and the scores of all the other efforts along the curve are adjusted (that is normalized) so that their sum equals 1000.

Next, management observes that the group of effort including C. G. B, D and H on the benefit-cost criterion curve has a higher total benefit for the same cost, than the group including B, G, C and F on the benefit-only criterion curve. Since B, C, and G are common to both groups, and if there are no interdepences [sic] among the research efforts, F can be compared with D and H. Let us assume management wants F's score changed to 205 to match the value of D and H. The change is made, the data is renormalized, and the adjustment process continues until management is satisfied with the final benefit scores for all efforts. Final benefit-cost data are computed (table 3), and a final set of curves are determined (fig. 2).

Figure 2 shows the nearly optimal order of investment for a dissimilar mix of effort. Note in figure 2, that for any arbitrary limit on cost, the best mix is defined. For example, if the 5-year budget is $1,000,000 then the best investment strategy is B, C. G, D. and part of F.

Note that the benefit-only criterion curve has now been raised so that it more nearly follows the more optimal benefit-cost curve.

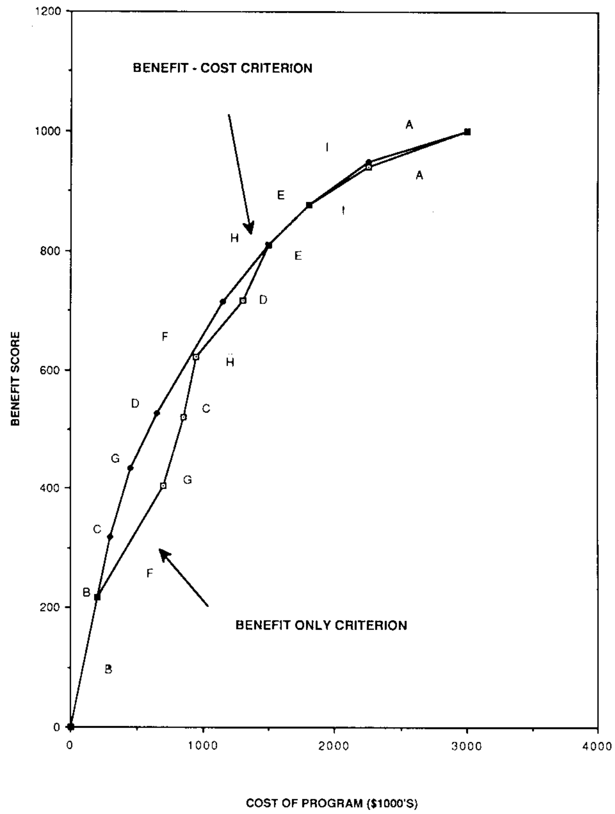

Figure 2--Final comparison of benefit cost vs. benefit only criterion.

This is the usual result of the management adjustment procedure.

In conclusion, the ratio-scaling and criterion adjustment system tied together worked well in evaluating intangible or at least incommensurable values in several studies including the RPA process.

However, a word of caution if you plan to use this methodology. Great care must be taken in preparing questionnaires and in analyzing results. In addition, the system will probably be unfamiliar to most of the participants so considerable effort must go into explaining and interpreting methodology and conclusions.

REFERENCES

Armstrong, Anne A. 1979. Decisions by design. Information World December: 24-25.

Davis, Jim; Marker, John. 1987. The wild land urban fire problem. Boston: National Fire Protection Association; Fire Command 54(1): 26-27.

Davis, J. B.; Shafer. E. L. 1984. The use of paired comparison techniques for evaluating forest research. Proceeding Soc. American Foresters. Portland, OR. 4 p.

Edwards, Allen L. 1957. Techniques of attitude scale construction. New York: Appleton-Century-Crofts, Inc.; 256 p.

Kahn, Robert; Wolf, Donald M.; Quinn. Robert P.; Snoek, J. Diedrick; Rosenthal. Robert A. 1964. Organizational stress: studies in role conflict and ambiguity. New York: John Wiley and Sons, Inc.; 470 p.

Richards, Max D.; Greenlaw. Paul S. 1972. Management decision and behavior. Homewood, IL: Richard D. Irving, Inc.; 655 p.

Shafer, Elwood L.; Moeller, George H.; Getty, Russel E. 1977. Future recreation environments. IS-316. Washington. DC: Forest Service. U.S. Department of Agriculture; 16 p.

Sinden, J. A.; Worrell, A. C. 1979. Unpriced values--decisions without market prices. New York: John Wiley and Sons. Inc.: 511 p.

Torgerson, W. S. 1958. Theory and methods of scaling. New York: John Wiley and Sons. Inc; 460 p.

USDA Forest Service. 1981. Criteria for deciding about forestry research programs. Washington, DC: General Technical Report WO-29. 52 p.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

The Fire Effects Information System[1]

William C. Fischer[2]

Abstract: Lack of information regarding fire effects is perceived by many fire and resource managers as a barrier to the effective application of prescribed fire. This lack of information, in many instances, is the result of poor diffusion of existing knowledge rather than lack of knowledge. A computerized Fire Effects Information System can make existing fire effects knowledge easily available to wildland managers. The system incorporates recent advances in the field of artificial intelligence to produce a virtual encyclopedia of fire effects information for plant species, plant communities, and associated wildlife species. At present, the system contains information pertaining to the sagebrush and pinyon-juniper ecosystems.

Prescribed burning is a popular and traditional forestry and range management practice. On western wildlands, fire is most frequently used to reduce fuel hazard, to increase quality and quantity of browse and forage, to enhance wildlife habitat, to prepare sites for regeneration, and to control undesirable vegetation. Using prescribed fire--including the prescribed use of chance ignitions--to maintain a more natural (presettlement period) environment in Wildernesses and on other essentially undeveloped tracts of Federal wildlands, is a relatively recent practice. It has significantly increased annual prescribed burned acres in many western National Parks and National Forests (Kilgore 1983).

Despite the current widespread use of prescribed fire, evidence suggests that its use would be even greater but for certain manager-perceived barriers. Several recent surveys of western wildland managers identified insufficient knowledge of fire effects and inadequate information for prescription development as the two most serious barriers to fire use (Noste and Brown 1981, Kilgore and Curtis in press). These surveys document a general need for fire effects information and prescribed fire guidelines, but specific information needs are not defined. The specific nature of these information needs was, however, reflected in the results of a delphi method survey of over 300 wildland managers and scientists regarding important research needs for understanding the effects of fire in western coniferous forests (Taylor and others 1975, Kickert and others 1976). Commenting on the results of this survey, Taylor and others (1975) make a significant observation regarding fire effects and prescribed fire information needs. They emphasized that answers to many of the questions asked by survey participants are already available in the existing literature, but that there is poor information diffusion from researchers to practitioners. This observation is reinforced by Thompson and others (1976) who note that only a small percentage of existing knowledge is being effectively applied by wildland managers.

This situation has not gone unnoticed. Recent attempts to better disseminate fire

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effects and fire use information abound. They include published literature reviews in the form of reports and textbooks, published and computerized bibliographies some of which contain abstracts, periodic lists of current literature, document delivery services, countless symposia on fire effects and prescribed fire along with their published proceedings, and a substantial increase in fire effects and use training opportunities. These information sources have undoubtedly resulted in improved application of fire effects information, especially by those managers willing to invest the time and effort to seek them out and use them. There are, however, shortcomings inherent in these forms of information diffusion. Literature reviews are often too general to apply to specific situations. And they are always dated: they only reflect the state of knowledge existing at the time they were written. Bibliographies and document delivery are invaluable for locating and obtaining literature, but the user still must extract, synthesize, and interpret the information in relation to his or her project. Most importantly, the results of diligent knowledge retrieval, synthesis, and interpretation are rarely preserved for use by others.

The Fire Effects Information System described here can provide wildland managers with ready access to fire effects information in a manner that avoids the shortcomings of current information dissemination techniques noted above.

DESCRIPTION OF THE SYSTEM

System Development

The Fire Effects Information System is being developed by the USDA Forest Service Intermountain Research Station at its Fire Sciences Laboratory, in Missoula, Montana. The system, developed in cooperation with the University of Montana Computer Sciences Department, is essentially a computerized fire effects knowledge base. Artificial intelligence concepts (AI) and techniques were used to design the system. Al is a subfield of computer science concerned with the concepts and methods of symbolic representation of knowledge to be used in making inferences (Feigenbaum and McCorduck 1984). AI was developed and continues to be developed for the purpose of creating knowledge-based systems. Knowledge-based systems are characterized by their ability to understand images and their reliance on a large knowledge base. Much of the current research and development in AI is directed toward construction of expert systems. An expert system is a knowledge-based program intended to take the place of a human expert by codifying the knowledge and rules the expert uses to reach his or her conclusion (Foster 1985). A major consideration for using AI techniques to design the Fire Effects Information System, which is not an expert system, was to ensure that its knowledge base would be compatible with future efforts to develop fire effects-related expert systems.

Information Provided

The Fire Effects Information System provides mostly text-type fire effects-related information in three major categories: plant species, ecosystems, and wildlife species. The ecosystem category includes three levels of classification: an ecosystem level, a cover type level, and a habitat or community type level. Within each of these categories information related to the following subject matter areas is provided by the system:

Category	Subject Matter
Plant species	Nomenclature and taxonomy
	Distribution and occurrence
	Value and use
	Botanical and ecological characteristics
	Plant adaptations to fire
	Fire effects
Ecosystem	
Ecosystem level	General description and characteristics
	Productivity
	Condition and trend
	Fire ecology and effects

	Cover type level	General description and site characteristics
		Value and use
		Fire ecology and effects
	Habitat type level	General description and site characteristics
		Fire effects and use
		Fire effects case studies
Wildlife Species		Nomenclature and taxonomy
		Distribution and occurrence
		Biological data and habitat requirements
		Fire effects and use

Within each subject matter area information is provided for a number of predetermined topics. For example, topical information contained in the fire effects subject matter area for plant species is as follows:

Fire effect on plant
Discussion and qualification of fire effect
Plant response to fire
Discussion and qualification of plant response
References
Fire effects case studies

In some cases topical information is presented with the aid of subtopics. For example, "Fire effects case studies" information in the preceding example is presented as follows:

Case name
Reference
Season-severity classification
Study location
Preburn vegetative community
Target species phenological state
Site description
Fire description
Fire effects on target species
Fire management implications

A portion of the information (species information, adaptation to fire, and fire effects) contained in the system knowledge base pertaining to bottlebrush squirreltail (<u>Elymus elymoides</u>), a widely distributed bunchgrass in semiarid regions of the West, is appended to this paper. This information is as a sample of the nature and organization of information provided by the Fire Effects Information System. Presented as part of the system in a similar manner, but not appended, is information on distribution and occurrence, value and use, botanical and ecological characteristics and fire case studies.

The above listed subject matter titles and the plant species information in the appendix show that the Fire Effects Information System provides more than the results of documented fire effects studies. Information on biological and ecological attributes of species is provided as an aid in understanding the documented fire effects and for inferring probable fire effects where documentation is scant or lacking. Information on seasonal development, for example, can aid in timing of fire treatments to obtain desired plant response. Value and use-related information is meant to aid in assessing potential damage from fire and for evaluating appropriateness of fire treatments in terms of management objectives. Information on distribution and occurrence should assist a user in identifying species and plant communities that should be considered when planning fire treatments. Much of the information related to classification systems--such as Raunkiaer life form, Grime plant and regenerative strategy classifications, Lyon-Stickney fire survival strategy, and Noble-Slatyer vital attributes--are included in the knowledge base for eventual use in conjunction with development of fire effects related expert systems.

System Design

As noted earlier AI concepts and techniques were applied to the design of the Fire Effects Information System. Foremost among these applications is the use of the LISP programming language, which is a symbol-manipulation language. The concept of symbol manipulation or symbolic processing is inherent in any AI system. Symbolic processing is a departure from the traditional use of computers to manipulate numbers (numeric processing). LISP has many desirable features for the development of a large, text-type knowledge base system. For example, the programmer need not identify in advance the exact size and structure of the data (knowledge) that will be processed by the program. Another desirable feature allows the integration of program instructions with data.

Frame-based knowledge representation is another Al technique applied to the design of the Fire Effects Information System. Knowledge representation refers to the technique used to store information in a knowledge base. Frames are a technique for representing knowledge that stores a list of an object's typical attributes together with the object. Each specific attribute of the object is stored in a separate slot. In the plant species information in the appendix, the frames are identified between the hatched lines. The slots are the information items or attributes listed beneath the hatched lines. For the FRAME TYPE: DISTRIBUTION AND OCCURRENCE, for example, the slots are GENERAL DISTRIBUTION, ECOSYSTEMS, STATES, ADMINISTRATIVE UNITS, BLM PHYSIOGRAPHIC REGIONS, KUCHLER PLANT ASSOCIATIONS, SAF COVER TYPES, HABITAT TYPES AND PLANT COMMUNITIES, and REFERENCES.

The use of LISP, frames, and other AI techniques resulted in the construction of a prototype Fire Effects Information System in a less time than was anticipated. This was due in part to the relative ease with which the programmers were able to make the many changes required during the early phases of system development.

System Structure

The Fire Effects Information System is made up of three main components: (1) the knowledge base, (2) the query system, and (3) the builder system. The knowledge base contains two types of information: (1) the plant, ecosystem and wildlife information provided by the system: and (2) the procedural information that tells the system how to do such things as display a data frame of a particular type, add or delete information from frames or frames from the knowledge base, and search for particular information (Mitchell 1986). Two components that can be considered as subsidiary to the knowledge base are the knowledge base interface and the print package. The knowledge base interface provides access to the knowledge base, while the print package controls the display of information from the knowledge base to the system user.

The query system is the user component of the Fire Effects Information System. In computer jargon, the query provides the user with a user friendly interaction interface to the knowledge base (Mitchell 1986). To the general user the query is the Fire Effects Information System. It displays the various information categories and subject matter area alternatives available and allows the user, through on-screen menus and prompts, to easily access any or all of the plant, ecosystem, or wildlife related information contained in the knowledge base. The information contained in the appendix for bottlebrush squirreltail is exactly as provided by the query system, only the on-screen menus and prompts have been eliminated to save space.

The builder system is a separate program that is used to add new information to the knowledge base or to update or otherwise change existing information in the knowledge base. It is assumed that access to the builder system would be restricted in to protect the integrity of the information provided by the Fire Effects Information System.

STATUS OF THE SYSTEM

An operational quality prototype Fire Effects Information System has been developed. Its knowledge base, built with strong support from the Bureau of Land Management (BLM), contains information for nearly 80 plant species, 10 wildlife species, and several cover types that occur in the sagebrush and pinyon-juniper ecosystems of the semi-arid West. The information in the knowledge base represents a painstaking effort on the part of fire research personnel to identify, locate, obtain, and then summarize existing fire effects and related information for the included species and communities.

The prototype Fire Effects Information System has recently been installed on a BLM Data General MV 10000 computer at the Boise Interagency Fire Center. The installation of this prototype will be operationally tested by the BLM during the late spring and summer of 1987. The prototype system was built on the University of Montana VAX 750 computer under the direction of Dr. Alden Wright. Knowledge base development continues to be accomplished on this machine. Knowledge base development will shift to a Data General MV 10000 computer at the

Intermountain Fire Sciences Laboratory, upon its installation during the summer of 1987.

A personal computer (PC) version of the query system has also been built. This PC version of the query is designed to run on IBM compatible machines with at least 640k of memory and hard disk capability. The compiled version of the builder system will also run on 640k; otherwise an AT-type machine with 2 megabits of memory is required. Software requirements include a Common LISP language package for main frame computers and Golden Common LISP for PCs.

Work is under way, with the cooperation and support of the National Park Service (NPS), to fashion the Fire Effects Information System to NPS needs. To this end, a knowledge base for Wind Cave National Park containing information on species and plant communities of the prairie ecosystem is being built. The system will be modified, as appropriate, to fit NPS needs.

REFERENCES

Feigenbaum, E.A.; McCorduck, P. 1984. The fifth generation: artificial intelligence and Japan's computer challenge to the world. New York: New American Library; 334p.

Foster, Edward. 1985; Artificial intelligence: beyond the buzz words. Personal Computing 9(4): 62-69.

Kickert, R.N.; Taylor, A.R.; Firmage. D.H.; Behan, M.J. 1976. Fire ecology research needs identified by research scientists and land managers. In: proceedings, Tall Timbers Fire Ecology Conference Number 14; 1974 October 8-10; Missoula, MT. Tallahassee, FL: Tall Timbers Research Station and The Intermountain Fire Research Council: 217-256.

Kilgore, Bruce M. 1983. Fire management programs in National Parks and wilderness. In: proceedings of the symposium: Fire--Its Field Effects; 1982 October 19-21; Jackson, WY. Missoula. MT: The Intermountain Fire Council and The Rocky Mountain Fire Council: 61-91.

Kilgore, Bruce M.; Curtis, George. A guide for prescribed understory burning in ponderosa pine-larch-fir forests in the Intermountain West. General Technical Report. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; In Press

Mitchell, James A. 1986. Object-oriented programming, LISP flavors and their application to a fire effects information system. Missoula: Univ. of Montana; 169 p. Thesis

Noste, Nonan F.; Brown, James K. 1981. Current practices of prescribed burning in the West. In: proceedings, 1981 John S. Wright Forestry Conference, Weed Control in Forest Management; 1981 February 3-5; West Lafayette, IN. West Lafayette, IN: Purdue University, Department of Forestry and Natural Resources: 156-169.

Taylor, A.R.; Kickert, R.N.; Firmage. D.H.; Behan, M.J. 1975. Fire ecology questions survey. General Technical Report INT-18. Ogden. UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 122p.

Thompson, K.M.; Ferry. G.W.; Hudson, R.; Leege, T.A.; Philpot, C.W.; Thompson, R.P. 1976. Are land managers applying our current knowledge of fire ecology? A panel discussion. In: Proceedings, Tall Timbers Fire Ecology Conference Number 14; 1974 October 8-10; Missoula, MT. Tallahassee, FL: Tall Timbers Research Station and The Intermountain Fire Research Council; 421-435.

APPENDIX

An example of the type of plant species information and its organization provided by the Fire Effects Information System. This example is for bottlebrush squirreltail (Elymus elymoides), a native perennial bunchgrass.

```
===============================================================================
SPECIES : Elymus elymoides
FRAME TYPE :  SPECIES
===============================================================================
SPECIES
    Elymus elymoides

ABBREVIATION :
    ELEL

SYNONYMS
    Sitanion hystrix
    Sitanion hystrix var. brevifolium
    Sitanion hystrix var. californicum

COMMON NAMES
    bottlebrush squirreltail
    squirreltail

TAXONOMY
    Barkworth and Dewey's 1985 treatment of the Triticeae combines the genus
Sitanion with the genus Elymus on the basis of morphological and cytological
evidence. Thus, Sitanion hystrix (Nutt.) J.G. Smith is now recognized as
Elymus elymoides (Rafin.) Swezey. Varieties of S. hystrix recognized by other
authors include: var. californicum (J.G. Smith) F.D. Wilson and var.
brevifolium (J.G. Smith) C.L. Hitchcock. These are now considered E. elymoides
[1]. Based on Wilson's study of Sitanion, Barkworth, and Dewey consider a
third variety, hordeoides (Suksd.) C.L. Hitchcock, to be a separate species and
recognize it as E. hordeoides (Suksd.) Barkw.& D.R.Dewey [1,6].

    In southern Idaho at the Saylor Creek Experimental Range, field studies
comparing growth and development between two varieties of S. hystrix (var.
hystrix and var. californicum) showed differences in biomass and rate of
development characteristics. Net photosynthesis, respiration, and
transpiration per unit leaf area were higher for var. hystrix. Optimum soil
temperature for seedling growth for both varieties was 13 deg. F (25 deg. C)
[3].

LIFE FORM
    Graminoid

COMPILED BY AND DATE
    W. Fischer, May 1986

LAST REVISED BY AND DATE
    K. Ahlenslager, November 1986

REFERENCES
    1: Barkworth and Dewey 1985
    2: Barkworth, Dewey. and Atkins 1983
    3: Hironaka and Tisdale 1972
    4: Hitchcock 1951
    5: Hitchcock, Cronquist, and Ownbey 1969
    6: Wilson 1963
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==
SPECIES : Elymus elymoides
FRAME TYPE : PLANT ADAPTATIONS TO FIRE
==
GENERAL ADAPTATIONS TO FIRE

The growth form of squirreltail is characterized by loosely clustered coarse culms (stems) with a minimum of leafy materials. During a fire, these culms usually burn rapidly with little heat transferred downward into meristematic tissue. Little charring of the crown below the soil surface occurs.

LYON-STICKNEY FIRE SURVIVAL STRATEGY

Ground-stored residual colonizer; fire-activated seed on-site in soil

NOBLE-SLATYER VITAL ATTRIBUTES

SPECIES TYPE

VT

TIME UNTIL ARRIVAL ON SITE (p) :

0-1 year

TIME UNTIL MATURITY (m) :

0-1 year

TIME UNTIL SENESCENCE (1) :

Infinity

TIME UNTIL EXTINCTION (e) :

Infinity

ROWE MODE OF PERSISTENCE :

Endurer

REFERENCES

1: Lyon and Stickney 1976
2: Noble and Slatyer 1977
3: Rowe 1983
4: Wright 1971
5: Wright and Klemmedson 1965
6: Young and Miller 1985

==
SPECIES : Elymus elymoides
FRAME TYPE : FIRE EFFECTS
==

FIRE EFFECT ON PLANT

Squirreltail is one of the most fire-resistant bunchgrasses. Its coarse leaves and low density of dead plant material within the bunch contribute to making it less susceptible to damage by fire. This is due to its rapid combustion with little downward transfer of heat into the root-shoot transition zone, located about 2 in. (4 cm) below the soil surface. Crown consumption by fire usually results in either no mortality or only slight damage.

DISCUSSION AND QUALIFICATION OF FIRE EFFECT

Older, ungrazed plants may be more vulnerable to injury because they often contain large quantities of dead material. Consequently, they burn hotter thereby increasing the probability of charring the plant below the soil surface, especially during severe burning conditions when upper soil moisture is often low. The probability of damage is less when plants are fully dried and dormant than when green and growing. Several instances of moderate to severe damage have been reported and are associated with burning in May [5,7]. Plants burned in mid-May in a drought year had 30 pct. mortality (73 pct. basal area reduction) while those burned in mid-June and October resulted in no mortality (48 pct. basal area reduction) [7]. In a sagebrush-grass range in southern Idaho, burns at 200 deg. F (93 deg. C) and 400 deg. F (200 deg. C) were conducted in each of three summer months. Plants burned in July showed a reduction in basal area, but were not killed. The production of flowering stalks decreased the year following the burn.

PLANT RESPONSE TO FIRE

Squirreltail often increases in abundance after a fire [2]. Preburn levels of annual production are usually achieved within 3 years, but often much sooner. Shoot biomass and density, and the proportion of reproductive shoots to all shoots may increase dramatically during the first postfire year [10].

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE

A seasonal reduction in basal area and reduction in herbage production may result from burning, especially in spring under severe burning conditions and on older plants containing large amounts of dead materials; but it may increase several years after burning [4].

REFERENCES

1: Blaisdell, Murray, and McArthur 1982
2: Countryman and Cornelius 1957
3: Mangan and Autenrieth 1984
4: Range, Veisze, Beyer, and Zschaechner 1982
5: Wright 1971
6: Wright and Klemmedson 1965
7: Wright, Neuenschwander, and Britton 1979
8: Young 1983
9: Young and Miller 1985
10: Zschaechner 1984

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Artificial Intelligence Applications to Fire Management[1]

Don J. Latham[2]

Abstract: Artificial intelligence could be used in Forest Service fire management and land-use planning to a larger degree than is now done. Robots, for example, could be programmed to monitor for fire and insect activity, to keep track of wildlife, and to do elementary thinking about the environment. Catching up with the fast-changing technology is imperative.

Just what is artificial intelligence (AI), and what could it possibly do for (or to) fire science and management? Before getting into uses that, as we shall see, will be manifold and pervasive, let us examine some of the characteristics and definitions of artificial intelligence.

Many potential or actual users of AI will insist that the term is an oxymoron, that is, anything artificial cannot be intelligent, and vice versa. There is a simple operational definition that gets us around this difficulty: the Turing test, named after its inventor, Allan Turing. If you are communicating with someone or something, and you can't tell whether the someone or something is human or machine, then it is intelligent. This test is simple, yet effective. We can expand this test just a little to include more behavior than communication, and we have a pretty good working definition of artificial intelligence along these lines: if it walks like a duck, quacks like a duck, and looks like a duck, then it's probably a duck.

I don't think there is any question that man can replicate his thinking processes in machinery and use machinery to expand those processes. We've already done this. We will build machinery that thinks to match the job to be done. Imagine coming to work one morning and turning on your desktop thinking machine, only to have it announce that it was calling in sick. It would probably really be fishing. So, we'd probably want our desktop machines to be rather subservient. On the other hand, suppose we send a machine to explore the surface of Jupiter. We would want this machine to have a great deal of intelligence, including the capability of refusing to carry out a self-destructive action (see Asimov's laws of robotics).

Where are we now in the realm of AI? Currently, the field is broken into several overlapping categories. The most common divisions are: environmental sensing (vision, hearing), including pattern matching and recognition of things; computer learning and analysis; "natural" language and linguistics; and reasoning, or knowledge-based systems ("expert systems"). Does this sound familiar? It should, because it is just what people do: input data from through their senses (or from internal sources such as a dream), filter and think about the data, apply known processes and remembered data to the result, and act on the result (fig. 1, 2). Some of our actions are

[1]Presented at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

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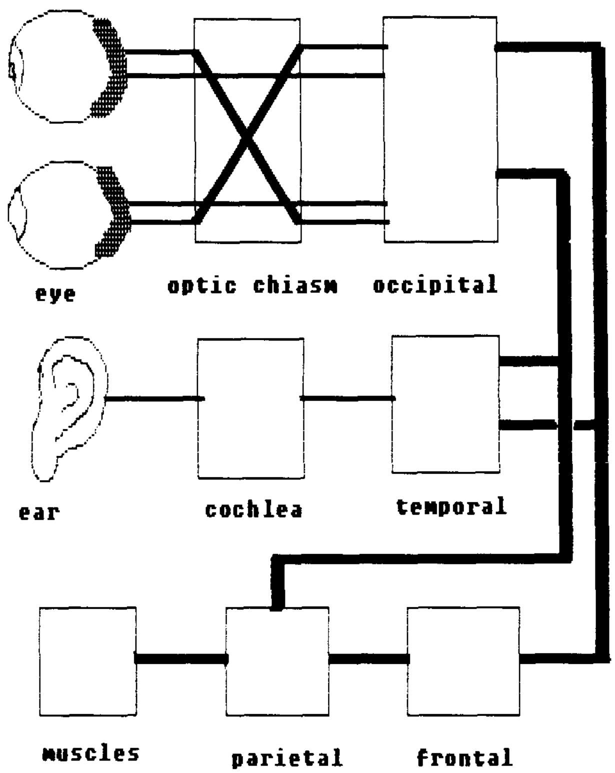

Figure 1--A simple-minded mind.

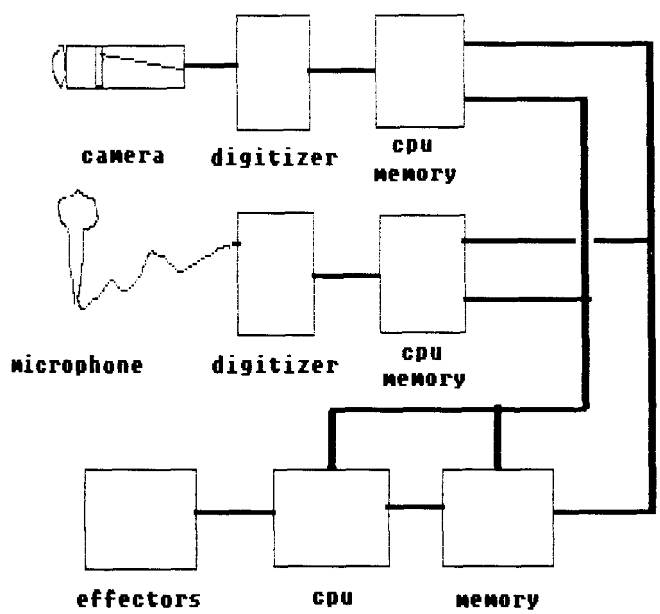

Figure 2--An artificial simple mind.

"hard-wired" like reflexes, some are "background" or meta-programs like driving a car, and some call for much active thought like reading this paper (I hope).

Each of these divisions of AI is in its embryonic stage. Every step forward seems to generate more questions than answers. Robotics, for example, a sort of melding of these arbitrary divisions of AI, is moving fast. Both military and commercial interests want robots to work for them: robots don't talk back, they obey orders, are dispensable, and cannot sue you. At present, however, robots are limited in capability. A robot van has successfully negotiated a road, on its own, at about 3 mi/h. Remotely piloted helicopters are being developed to recognize tanks using infrared scanners and knowledge-based systems. Does that sound like something desirable for fire application?

Presently, the most useful AI technology is the expert system. These computer programs (to put them in their place) use knowledge bases. composed of facts and rules, interpreters of the facts and rules called inference engines, input and output routines, and explanation routines (fig. 3). Most of these programs follow long and sometimes tortuous reasoning chains to a conclusion. They are good at this, whereas

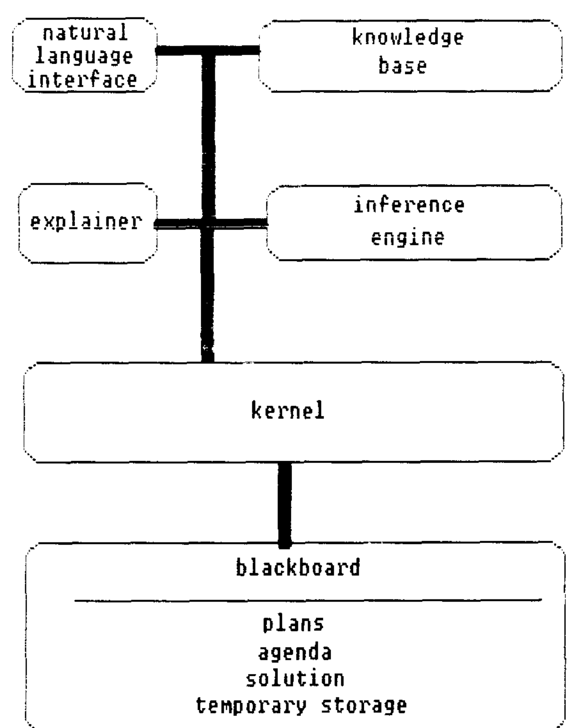

Figure 3--A contemporary expert system.

people are not; it is not a survival characteristic. A person engaging in long reasoning chains when threatened by a saber-tooth tiger probably would get eaten.

An expert at something has created a domain of knowledge about the something. Within that domain, the expert has formed heuristics, or rules-of-thumb, to guide activities. If the expert can--with the aid of a knowledge engineer, or without--codify his or her knowledge, an expert system can be constructed to mimic the behavior of the expert in the domain. The codification and the knowledge base that results are knowledge representation, one of the major problems in expert systems. This process is, of course, putting the expert's knowledge into machine-understandable format.

<u>Why not just teach the machine to accept the knowledge and codify it, thus replacing the knowledge engineer with a program?</u> Attempts to do just that are ongoing. It is one of the current hot topics in artificial intelligence.

Of course, the program, unlike the expert, is not able to extend the knowledge base in other than an elementary deductive way. Once we have started the program and it has deduced all the consequences of the knowledge it has in its knowledge base, it stops. We have not told the program how to extend its knowledge. The machine's extension of its knowledge is, as you might expect, one aspect of machine learning. The program has to know not only how to learn or store data, but also how to form and test new hypotheses about new input. To do that, the program has to know how to think about thinking, and so on.

<u>If our understanding of how to build effective machines is so infantile, then what good, in a practical sense, are the simple programs that are available to us?</u> Right now, we can computerize any repetitive process or any closed operation for which a knowledge representation can be found. We can also generate programs that add facts within the representation to their knowledge bases, and reason using those new facts. We can construct intelligent databases and inventory systems. If we had started work 5 years ago, in a serious way, we could right now be using:

--an expert system that is the Forest Service Manual on Fire Management
--a semi-automated land-use planning system
--an elementary reasoning fire dispatch system
--prescribed burning plans that learn
--interactive, self-correcting, geographic information systems

Many of these would have been available this year or during the next couple of years on cheap mass storage and running on advanced workstations, large desktop computers. We are, then, at least 5 years behind.

<u>If we rush to catch up, how far could we get by the year 2000?</u> We could be testing or have:

--the first crude robots for forest use
--completely automated fire dispatch machinery that would be able to use the forest robots as smokechasers
--interactive teaching tools

A robot for a forest or rangeland would be programmed to roam a given geographic area, monitoring for fire and insect activity, keeping track of wildlife, and the like. It could be programmed to do elementary thinking about its environment and would call for help if needed. Of course, it knows where it is by satellite navigation, presently available.

Fire dispatch machinery such as I describe is already beginning to be used, except for the robotics, in Ontario and Quebec. The package and concept were developed by Peter Kourtz at Petawawa. The machine dispatcher keeps track of fuels by satellite, rainfall by radar, and weather and lightning occurrence by land-based sensors. It is at present dependent on human input, but will become more and more intelligent as time goes on.

<u>Do such machines and programs replace people?</u> Yes, of course. They replace people who are doing mundane, repetitive tasks, tasks that almost all people dislike and perform poorly. Machines and programs free people to do what they do better than machines--think creatively and with common sense. The machinery must be looked at as a tool, as an extension of the mind and body. Look--did the bulldozer replace the Pulaski? Sure, for some uses, but each still has its place.

Aside from cost, which is a matter of commitment to a course of action, the things that hold us back from implementation of this or other new technology are simple human inertia, a reluctance to change, and a management system firmly rooted in the 19th century.

Resistance to change, however, is a survival trait. New things must be tested to assess their value. What I am doing is proposing that application of new technology is more than just developing a better way of finding and putting out a fire, or even better planning tools. It now includes change in a chain of command with information and policy implementation passing through many layers, to a system two or three layers deep and with far more automated information passing. We are seeing the bare beginnings of this with the Forest Service-wide computer system. It is starting as an aid within the old management structure, but will sooner or later enable a far more efficient structure. releasing managers from much of the paper shuffling necessary for passing information through a vertical structure. We will move from turf to meta-turf. And artificial intelligence programming techniques will be helping us all the way.

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Fire Effects, Education, and Expert Systems[1]

Robert E. Martin[2]

Abstract: Predicting the effects of fires in the year 2000 and beyond will be enhanced by the use of expert systems. Although our predictions may have broad confidence limits, expert systems should help us to improve the predictions and to focus on the areas where improved knowledge is most needed. The knowledge of experts can be incorporated into previously existing knowledge bases, and the process of extracting knowledge from experts will help the expert to make more astute observations and to examine the judgments made. Expert systems also have potential in educational and training processes. By building a small expert system, the student will be aided in synthesizing facts into principles.

Expert systems are relatively new to most of us in fire science and management, so I will explain many of the terms as I proceed. In each section, along with the explanation I will talk about where we are, how we got there, and look at some projections of where we will be by the year 2000 and beyond.

This prediction is particularly difficult in the field of computers because of the rapid progress in the field. Hardly anyone would have dared to predict the present state of personal computers 10 years ago. Computers of all sizes are growing rapidly in their ability to store information and to process it. By the year 2000, we can expect to have desktop computers that rival all but the very fastest and largest computers of today. Although these computers will probably cost somewhat more in real dollars than today's desktops, their cost per unit of capability will go down.

This paper introduces the idea of expert systems, their potential in fire effects, and how they might improve the education and training process. The example I use deals with fire effects, but the potential is there to use it in other fields of fire science and management, and all fields of natural resource management.

I will first talk about expert systems as a branch of artificial intelligence, then about computers and the languages used--especially those which are prominent in the field of expert systems. Next I introduce the idea of an expert system as it might work in a very simple fire effects problem. This discussion will also look at how we might expect these systems to work in the future. The third section will cover how expert systems systematize experts' knowledge, making it more available and more accurate. Finally, we'll look at the potential for expert systems in education and training where it may help students develop a more integrative knowledge.

EXPERT SYSTEMS AND ARTIFICIAL INTELLIGENCE

Expert systems make up one branch of the broader field of artificial intelligence. I question whether either is a good term, but I use them because of their general usage in the literature. The other two branches are natural language and robotics.

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Natural language, as the name suggests, deals with developing computers that are able to understand language closer to that which we use everyday. The declarative languages discussed below are more natural than those we are most familiar with. In the future, computers should be able to understand spoken commands as well, and significant progress is being made in this field.

Robotics is the third branch of artificial intelligence. It deals with the ability of computers to sense their environment and thus move about and perform acts without close human supervision. By the year 2000, the sensing instruments may work from radiation, temperature, odor, touch, and sound--the same senses by which we move about and perform. Since they would move about without the emotions (unless emotions were programmed in as responses to certain stimuli) the robotic could move about and work without fear, anger, or passion. The lack of emotions could also be detrimental to the robotic.

COMPUTERS AND LANGUAGES

Computers as we know them today are basically number crunching machines. This design for computers evolved shortly after World War II when the British and Americans both began working on computers. The British thought of the computer in a broader context as a logic machine, whereas Americans approached the computer as a means of rapidly manipulating large data bases. Computer development until now has mostly followed the American concept, and we have computers that can process millions of bits of information each second. Further, the ability to process information is increasing at a rapid rate.

Present computers are inefficient and slow as logic machines, which means they don't work as well as they might for expert systems. This situation might change as we see new generations of computers developed. Although such machines are being developed in many countries, the Japanese have undertaken an initiative to develop a fifth generation computer based on the declarative PROLOG language. Before the year 2000, we should have these new computers linked with our present types of computers, allowing each to function on those parts of problems on which it does best. The PROLOG-based computer will handle the logical part, and it will send the number-crunching to the data manipulation machine. We will probably see the two types combined in one computer.

The higher level computer languages can be divided into two groups--procedural and declarative. The procedural languages, with which more of us are familiar, tell the computer how to do something. Some of these languages are FORTRAN. COBOL. and PASCAL. The declarative languages tell the computer what one wants done and lets the computer figure out how to do it. The two main declarative languages are LISP and PROLOG. There are variations to each language, depending on the implementation. LISP is a contraction of LISt Processor, and PROLOG is a contraction of PROgramming in LOGic.

The declarative languages have probably not progressed as far as the procedural languages, relatively. There are still many variations of both LISP and PROLOG, and more variations are arriving on the scene. The incompatibilities among these, combined with the different capabilities, make it difficult for the user to select the best alternative. A recent arrival has been Turbo-PROLOG, which is quite different and more structured than other versions. The confusion among the different versions should decline in the next several years, and the general use of the languages increase dramatically.

Another problem in the use of the declarative languages has been their provincial nature. Until a few years ago, LISP was primarily an American language, and PROLOG was European. This separation is now disappearing, which may lead to improved interlanguage communication.

SAMPLE EXPERT SYSTEM

An oversimplified example illustrates how expert systems can be used to predict fire effects. The example uses Turbo-PROLOG, a variant of the language quite different from other PROLOGS.

I consider four situations relative to short term fire effects:

(1) Previous fire, known characteristics- such as fireline intensity, fuel consumption temperature, wind;

(2) Previous fire, observed effects- the effects of the fire, such as bark and crown scorch height, fuel remaining;

(3) Future fire, given characteristics-
fire behavior, fuel consumption, crown scorch, bark char, temperature;

(4) Future fire, given conditions-
fuel and weather conditions and whether fire is heading or backing

From these, for our simplified example, we use fireline intensity and fuel consumption as the fire characteristics. I will build the example in Turbo-PROLOG, which has the following sections to a program: Domains, Predicates, Clauses, and Goals.

First, we must define the type of data to be represented by various names in the program. Thus, in the Domains section, we have the following statement:

DOMAINS

vegetation, fire_characteristics = symbol.

The Predicates section provides Turbo-PROLOG with the format of any fact or rule statement to be used in the Clauses section. We provide the following:

PREDICATES

kills (fire_characteristics, vegetation).

The Clauses section is the real heart and brains of the program and contains the statements of facts and rules that make up the knowledge base with which we are working. Generally, this will be by far the largest section of the program. For our program, we enter the following:

KNOWLEDGE BASE

CLAUSES

kills(fire_intensity_50, abco_0-2_90%).
kills(fire_intensity_50, abco_2-4_70%).
kills(fire_intensity_50, abco_4-8_40%).
kills(fire_intensity_50, abco_8-12_10%),

kills(fuel_consumption_10,abco_0-2_95%).
kills(fuel_consumption_10,abco_2-4_80%).
kills(fuel_consumption_10,abco_4-8_40%).
kills(fuel_consumption_10,abco_8-12_15%).

Finally, to get an answer to a question, we must define a Goal. This could be included in the program as a single goal. Generally, for our program, we will want to ask different questions at different times, so we will provide different goals for the program to satisfy. The program will search its knowledge base for all sizes and in every plant species listed where greater than 20 percent of the plants are killed by a fuel consumption of 20 tons per acre. From the small knowledge base we've given it, the computer would respond as follows:

GOAL:

kills_greater than_20 o(fuel_consumption_10,X).

abco_0-2_95%
abco_2-4_80%
abco_4-8_40%

GOAL:

At the end, the computer has answered the goal given it and is asking for another goal.

The knowledge base and the problems we gave the computer are very limited and the answers not very helpful. We would want to make the system better by using information such as Van Wagner's (1973) scorch height equation. This could be programmed into a procedural language. A good way to do that would be to use Turbo-Pascal because Turbo-PROLOG can interact with it.

Similarly, most expert systems today in natural resources are quite limited and narrow. The question is, where can we go with more powerful systems in the future. Experts in the field of expert systems foresee a great expansion in the capability of expert systems in the early 1990's. Computers will be far more efficient in handling the declarative languages, and we will have language enhancements that allow us to build extensive systems.

Perhaps our systems in the future might be linked as shown in figure 1. Here we have a combination of several components. The knowledge of experts is gleaned by "knowledge engineers" who feed this into what we today call a shell for the expert system. In the next step, we may combine the knowledge of several experts and some data to form a knowledge base from which the user can extract logical decisions. Finally, the expert system may request the procedural language to perform operations or calculations using functions stored in one or the other, using the manipulation efficiency of that language.

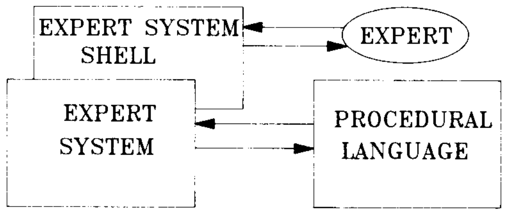

Figure 1--Expert systems will be integrated with input from experts and procedural languages to do calculations.

If we combine all this with the use of natural languages, so we are not stuck with punching keys or pushing a mouse, our interaction with the computer should be far simpler. We can expect a greater familiarity and confidence of our personnel in handling computers in the future. Thus, we should be spending far less time working "for the computers" and getting far more information from them.

SYSTEMATIZING EXPERTS' KNOWLEDGE

Expert systems may help systematize the knowledge of experts. By doing so, we may tend to make experts more expert--and we may end up with fewer experts.

The first point is that if an expert writes down the points by which he or she arrives at a decision, both that expert and others will be able to examine more critically each step. Although this may deter experts from writing the material, more will be gained from the critical review. The expert is forced to be more explicit and consistent. The bases the expert uses are subjected to examination.

Writing the material down helps to identify important information as well as where more information is needed. As one proceeds through a decision process, some information will become more important, other less. Further, confidence limits that can be placed on each piece of information will help decide its importance. Thus, a piece of information with a high confidence limit and to which the problem is quite sensitive would be quite important. In contrast, low-confidence-limit information with low sensitivity would have low importance.

The use of our knowledge in expert systems will help us to identify where more information is needed. If we find a problem is quite sensitive to certain information but have little or no information or low confidence level in it, then we would want to improve our knowledge in that area. Further, the expert system should help us to evaluate where more information is needed. When a problem is addressed through the logic and analysis of expert systems, those areas where information is missing, or of insufficient accuracy will become apparent.

EXPERT SYSTEMS IN EDUCATION AND TRAINING

Expert systems should have a large role in improving education and training. Since education deals more with how one uses the mind, and training more with response to a given stimulus, perhaps expert systems will play a greater role in education than in training. Looking at the situation from a different perspective, we might spend considerable time training people to use expert systems.

Expert systems might help in education in three main ways. First, expert systems can help students synthesize knowledge. By bringing the detailed knowledge together into a base with a systematic means of querying for certain answers, the data from different bases will be combined and synthesized.

Second, expert systems can help the student, and even the teacher, to think of problems in a structured way.

Third, experiential learning might be enhanced by expert systems. The predicted results of given actions can be obtained through querying the knowledge base. Thus, either by itself or as an enhancement to experimental work, expert systems should help the student to learn by experiencing an answer to given actions.

A look at our knowledge would indicate that we have deep knowledge and surface or integrative knowledge (fig. 2). Our formal education in school is involved with acquiring the deep knowledge of subjects where we learn first principles, axioms, and laws. From mentors and experiences, we acquire the integrative knowledge that helps us to apply our deep knowledge in solving practical problems.

As we progress through life, we acquire both the deep and integrative or surface knowledge. Professionally, I prefer to call it integrative

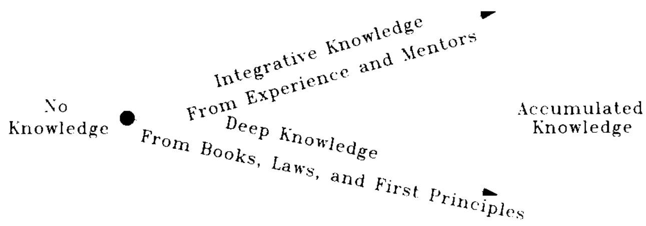

Figure 2--Diagram of our acquisition in integrative and deep knowledge (modified from Harmon and King 1985).

because that's how we combine the deep knowledge in several subjects hopefully to arrive at logical and wise decisions. It is in this integrative area where expert systems may have an important role in professional development.

The process of using expert systems in a classroom could proceed in the following order (Starfield and Bleloch 1986). First, the idea of expert systems would be introduced. Second, the professor and class would discuss areas where small expert systems would be useful. Third, groups of students would develop a small knowledge base. Finally, the small systems would be demonstrated and critiqued.

SUMMARY

Expert systems are relatively new and are just now beginning to be used in natural resources. As the declarative languages are improved and the fifth generation of computers becomes available, we can expect to see much broader and more powerful expert systems developed. The improvement in natural languages for computers will enhance expert system development and use.

The fire manager of the future will be using expert systems to predict fire effects as well as other fire functions. Through their use the manager will be able to develop integrative knowledge more rapidly, be able to take into account pertinent factors in analysis without forgetting any of them, and hopefully arrive at better decisions more rapidly.

REFERENCES

Harmon, Paul; King, David. 1985. Expert systems. New York: John Wiley and Sons; 283 p.

Starfield, A.M.; Bleloch, A.L. 1986. Building models for conservation and wildlife management. New York: Macmillan Publishing.

Van Wagner, C. E. 1973. Height of crown scorch in forest fires. Can. J. Forest Res. 3(3):373-378.

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Fire Behavior System for the Full Range of Fire Management Needs[1]

Richard C. Rothermel and Patricia L. Andrews[2]

Abstract: An "integrated fire behavior/fire danger rating system" should be "seamless" to avoid requiring choices among alternate, independent systems. Descriptions of fuel moisture, fuels, and fire behavior should be standardized, permitting information to flow easily through the spectrum of fire management needs. The level of resolution depends on the application, but the same central processor can be used. Three tasks must be carried out to reach the goal: (1) determination of fire management needs, (2) development of a central processor to be used as the core of the system, and (3) development of the individual subsystems with a framework for moving between them.

One of nine research initiatives proposed by the director of Forest Fire and Atmospheric Sciences Research staff in the Forest Service's Washington office is an "Integrated Fire Behavior/Fire Danger Rating System" (Philpot 1985). The initiative states: "A single, integrated system that can accommodate the full continuum of spatial/temporal resolution requirements--from National, long-range fire severity forecasting to real-time suppression strategy decisions on actual fires--is needed to meet the varying fire behavior information needs of wildland managers."

The need for an integrated fire behavior system designed for the full range of fire management needs has come about for several reasons:

1. Proliferation of systems based on fire behavior has resulted in confusion in the choice of the appropriate system for a specific fire management need.
2. It is difficult to make the transition from one system to another when moving from the planning to operational phases.
3. Requirements placed on tire managers for analysis and planning are much more demanding than in the early 1970's when the current fire behavior and fire danger systems were formulated. We expect this trend to continue.
4. There have been significant advances in fire research.
5. The technology available for reaching fire managers and assisting them is increasing dramatically.

A fundamental concept of the system envisioned in the initiative is that it be "seamless." or integrated, to avoid requiring choices among alternate, independent systems. Descriptions of fuel moisture, fuels, and fire behavior should be standardized, permitting information to flow easily through the spectrum of fire management needs.

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We see three tasks as necessary to carry out the initiative:

Task 1. Determine the needs of fire managers for systems centered around fire behavior. Develop a plan that specifies the necessary subsystems, such as long-range planning, prescribed fire planning, fire danger rating, and dispatch. The plan should outline the span of operations for each subsystem with emphasis on their interaction.

Task 2. Develop a central processor containing the mathematical fire behavior prediction models that will serve as the core for all subsystems.

Task 3. Develop the subsystems using the new central fire behavior processor according to the plan defined in task 1. Develop a framework for accessing subsystems and moving between them.

The first two tasks can be carried out in parallel. There is a long lead time and there will be ample time for coordination. Planning for the third task can begin when the subsystems are identified, but actual development of the subsystems will depend upon completion of the central processor.

Developing a plan for the systems needed by operating agencies (task 1) should be the responsibility of those agencies with support from research. Developing a central processor for the systems identified in the plan (task 2) should be the responsibility of research with support from the operating agencies. Responsibility for developing the subsystems (task 3) will probably fall upon both research and the operating agencies. This third task is several years away.

NEED FOR THE INITIATIVE

Number of Systems/Confusion in Application

Since 1972. many systems have been developed to meet the expanding needs of fire management. Although fire behavior and fire danger rating are specifically mentioned in the title of the initiative, those are only two of the systems involved. Another system that is used nationwide by the Forest Service is the National Fire Management Analysis System (NFMAS) (USDA Forest Service 1983). Other examples are FIRECAST (Cohen 1986), RXWTHR and RXBURN (Bradshaw and Fischer 1981), HAZARD (Brown and others 1977), the National Fuel Appraisal Process (Radloff and others 1982), and the Initial Attack Management System (IAMS) (German 1985).

The National Fire Danger Rating System (Deeming and others 1977) was designed as a prefire planning tool. It is basically a seasonal weather processor. The indexes it produces are relative values that rate fire danger over broad geographic areas.

The fire behavior prediction system (FBPS) is based on concepts described by Rothermel (1983). It was designed to predict actual fire behavior and allows the user to tailor the resolution of the input to meet the application. The FBPS is available through a number of computing methods as summarized by Andrews (1986a). One of the most widely used methods is the BEHAVE fire behavior prediction and fuel modeling system (Andrews 1986b, Burgan and Rothermel 1984).

NFMAS is used to evaluate long-term consequences of alternative fire protection programs for relatively large planning writs. It is essentially a hybrid of NFDRS and FBPS. NFMAS uses the danger rating equations and fuel models. However, it uses site-specific input and interprets output in terms of actual fire behavior.

In addition to national systems, individual administrative units have designed their own systems for assisting them in both long-term planning and day-to-day operations. A specific example i3 the Mt. Hood Field Guide for Appropriate Suppression Response (USDA Forest Service 1985). It is based on tables of predictions generated by BEHAVE.

it is understandable that there is confusion on proper application of the many fire management systems. However, there is a positive aspect to the large number of systems based on fire behavior. The utility of deterministic mathematical models structured into decision processing systems has proved to be a highly effective and readily adaptable method of assessing fire management problems.

Difficult Transitions

Almost all current fire management systems are based on a mathematical model designed to predict the spread of a steady-state surface fire (Rothermel 1972, Albini 1976). There are, however, significant differences in the equations as they are used in NFDRS. Developers of other systems (e.g., NFMAS) have had to decide which set of equations to use. The difficult transition from one system to the next is caused by the difference in equations (the central processor).

The most visible aspect of this problem is the fact that there are two sets of fuel models. Fuel models are designed to work with a specific set of equations. If a fuel map is produced for use by NFMAS, it has NFDRS fuel models, and cannot be easily used for fire behavior prediction applications.

Changing Needs

If the National Fire Danger Rating System and the Fire Behavior Prediction System satisfied all of the needs of fire managers, there would not be the need for the initiative. Fire management, however. has become more complex since those systems were developed. The following are examples of the changing needs of fire managers:

--Managers now have options other than strict fire control. Unplanned ignitions may be declared prescribed fires rather than wildfires if they meet criteria set up in a tire management plan. In addition, there are options on the level of suppression action that might be taken on a wildfire; in Forest Service terminology, Contain/Confine/Control.

--Smoke production is becoming an overriding concern in connection with prescribed fire. The window of acceptable burning conditions may be quite narrow, making it critical that an acceptable day not be missed.

--Restricted budgets make it important that correct decisions be made on fuel treatment options using the best information available on expected consequences.

--The encroachment of homes into forest areas is causing a major problem for forest protection agencies.

--Prescribed fire is much more than the attainment of "black acres." More emphasis is being put on fire effects.

--Fire is just one aspect of the total resource management job and is becoming more integrated into the overall planning process.

--Forest managers often have duties that include more than fire. Fire behavior systems that are compatible and easy to use can help them make the best use of their time and help assure careful consideration of options without excessive tedium.

Available Research

Even if there were no compatibility problems with the current systems, it is time to begin planning a major change. The existing fire spread model is 15 years old and should be updated. Models are also needed for crown fires and smoldering ground fires. Other models are needed to supply inputs to these new fire models.

Advances in Technology

A trend that is most likely to continue and one that will have a large effect on the form of our product is the explosive advancement of technology. When the current fire danger rating and fire behavior prediction systems were developed, they were offered on mainframe computers using punch cards, and as publications of tables and nomograms. We have since progressed to using interactive programs on in-house computers, desk-top computers, and micro chips developed for handheld calculators. New systems will be able to take advantage of satellite mapping of fuels for large areas, geographic information systems, graphic output of results, telecommunications linking all levels of management, personal computers, and far more.

DEVELOPMENT OF THE CENTRAL PROCESSOR

The structure of a system is based on a flow of information from inputs through the central processor to outputs. It is the fire behavior models and their related input and output models that we refer to as the central processor. This basic structure is altered to meet specific management needs by specifying methods for obtaining inputs required for certain operations. Inputs for planning may come from historical data bases, while real-time fire prediction requires up-to-the-minute data. Similarly, output is tailored for certain applications. This may involve maps that display levels of fire danger or suppression cost-plus-net-value-change analysis.

The use of mathematical models to predict fire behavior, fuel moisture, etc., has proved to be such a powerful technique and adaptable to so many fire management activities that the development of these models will continue to be the primary goal of our research.

Our knowledge of fundamental fire behavior and the factors controlling fire is still limited. A long list of items needing attention can be made quickly. Among the more challenging in the list are the nonuniform fuel problem, crowning, spotting, combustion of living fuels, burnout of large fuels, smoke production, and wind flow in rough terrain. Research results are available on some of these problems and research must continue, particularly in regard to arriving at general solutions that can be adopted in national systems.

Development of the central processor is not expected to be a crash program. The research emphasis for the next 3 to 5 years will be on fundamental research and model development. Because there are so many areas needing investigation and because of limited scientific staff, we must concentrate on the areas of highest priority.

Crown Fires and Spotting

Crown fires have aroused renewed interest. The Canadians have incorporated good field data in their system for quantitative fire behavior prediction (Lawson and others 1985). Albini (1986) made a strong effort at modeling the spread of crown fires, but the model is far from being ready for field application. We currently think that the biggest question is whether a surface fire will develop into a crown fire, i.e., identifying the conditions for the onset of crowning. Van Wagner (1977) has characterized the types of crown fires and their dependence on the surface fire. We believe that a detailed examination of the ignition-moisture relationship, especially as influenced by drought, needs further explanation.

Spotting is not restricted to crown fires, but is usually associated with severe fires of some type. It is one of the most intractable problems we face. Methods for predicting the distance firebrands will travel and still be burning are already in use (Albini 1979, Albini 1981, Albini 1983, Chase 1984). However, the ability to estimate the number of spot fires actually started remains a difficult problem.

Surface Fire Model

Research under way for several years is designed to increase our capability for predicting the behavior of fire in surface fuels. One of these efforts has been to define the limits of combustion. Better information about the probability of whether a fire will be sustained in a steady state condition is vitally needed. This research, begun originally to define the moisture of extinction, has gone well beyond that and will form the basis of a new fire spread model. It is being couched in stochastic form so that the probability of fire spread can be defined (Wilson, in press). The concepts have been developed using data from a much wider range of fuel sizes and loading conditions than were used in the original fire spread model. The research must be expanded to include the effect of wind, slope, and green fuels.

Significant progress has also been made in the area of fuel chemistry. We now have analytical instrumentation capable of determining the heat required to bring fuel up to ignition and for determining the heat available from both flaming and glowing combustion (Susott 1981). This information will form the basis for all new combustion models. We have a considerable amount of data, and a library of fuel particle properties is being developed.

Ground Fires

We need the characterization of smoldering in forest duff to estimate fire effects, the probability of holdover fires, and the probability of detection. Ground fires often occur in highly compacted fuel for which the surface fire spread model is not suited.

In addition to field work on duff consumption (Sandberg 1980, Brown and others 1985), a carefully designed laboratory study (Frandsen 1980) is closely examining combustion of duff and will provide the basis for models of the phenomenon.

Related Models

Input to the ground, surface, and crown fire models will often be the output of other mathematical models. Fuel moisture and fuel models are examples.

Although fuel moisture is sometimes determined from direct sampling and drying, it is more often calculated. Some recent significant results (Anderson 1985) indicate that we will probably have to abandon the idea that all fine fuels have 1-hour time constants for moisture response.

Description of the fuel geometry and load as an input to the surface fire spread model is currently put in terms of a fuel model. The fact that there are two sets of fuel models, 13 for FBPS and 20 for NFDRS, has caused considerable confusion. The spread model works under the assumption that fuels are uniform and continuous. In the field, however, that is the exception rather than the rule. The contribution of large fuels to fire problems must be included in future models and systems. In addition, we will have to learn to describe fuel for the ground and crown fire models as well as surface fires. The whole fuel issue needs to be reexamined closely and a fresh approach actively pursued.

SYSTEMS DEVELOPMENT

Simultaneously with work by research on the central processor, the operating units should be examining their needs and developing specifications for the systems envisioned for the future. Good coordination should be maintained between research and the operating agencies to assure realistic goals. One step in examining fire management needs should be a survey of applications that are based on the current fire spread model and definition of the needs they fill.

Careful consideration should also be given to an overall framework to tie the subsystems together. It is not expected that one computer program would contain all of the subsystems; it would be too large and unwieldy. A user-friendly interactive computer system using expert system techniques may help fire managers identify and access the subsystem appropriate to specific needs.

Although the equations in the new central processor may be more complex than those in current systems, the complexities will be invisible to the user. At present, much energy is put into explaining the differences in the central processors and fuel models of the NFDRS and FBPS. Basing all subsystems on the same central processor will eliminate this problem. In addition, the system of the future will be easier to use and understand due to more user-friendly interfaces, interactive exchange between the computer and the fire manager, and presentation of results in graphic formats.

SUMMARY

It is time to look at an integrated fire behavior/fire danger rating system that can meet the whole range of fire management needs. The large number of systems in use sometimes leads to confusion in proper selection and application. It is often difficult to make the transition from one system to another. The situation could be simplified by basing all subsystems of the integrated system on the same central processor and by providing a framework for accessing subsystems.

Development of the mathematical models that go into the central processor will be the primary responsibility of research. Operational agencies should take the lead in assessing needs and in developing a plan that specifies the necessary subsystems to fill those needs. This work will require careful coordination among researchers, system developers, and fire managers to ensure that the system meets fire management needs of the future.

REFERENCES

Albini, Frank A. 1976. Computer-based models of wildland fire behavior: a user's manual. Ogden, UT: Intermountain Forest and Range Experiment Station. Forest Service, U.S. Department of Agriculture; 68 p.

Albini, Frank A. 1979. Spot fire distance from burning trees.--a predictive model. Gen. Tech. Rep. INT-56. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 73 p.

Albini, Frank A. 1981. Spot fire distance from isolated sources-- extensions of a predictive model. Res. Note INT-309. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 9 p.

Albini, Frank A. 1983. Potential spotting distance from wind-driven surface fires. Res. Note INT-309. Ogden. UT: Intermountain Research Station, Forest Service, U.S. Department of Agriculture; 27 p.

Albini, Frank A. 1986. A model for fire spread in wildland fuels by radiation-a model including fuel cooling by natural convection. Combustion Science and Technology (45): 101-113.

Anderson, Hal E. 1985. Moisture and fine forest fuel response. In: Proceedings of the 8th Conference on Fire and Forest Meteorology: 1985 April. 29-May 2; Detroit, MI. Bethesda, MD: Soc. Am. Foresters; 192-199.

Andrews, Patricia L. 1986a. Methods for predicting fire behavior--you do have a choice. Fire Management Notes (47)2: 6-9.

Andrews, Patricia L. 1986b. BEHAVE: fire behavior prediction and fuel modeling system--BURN subsystem, Part 1. Gen. Tech. Rep. INT-194. Ogden, UT: Intermountain Research Station. Forest Service, U.S. Department of Agriculture; 130 p.

Bradshaw, Larry S.; Fischer, William C. 1981. A computer system for scheduling fire use, Part 1: the system. Cen. Tech. Rep. INT-91. Ogden. UT: Intermountain Forest and Range Experiment Station. Forest Service. U.S. Department of Agriculture; 63 p.

Brown, James K.; Marsden, Michael A.; Ryan. Kevin C.; Reinhardt. Elizabeth D. 1985. Predicting duff and woody fuel consumed by prescribed fire in the Northern Rocky Mountains. Res. Pap. INT-337. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 23 p.

Brown, James K.; Snell. J.A. Kendall; Bunnell, David L. 1977. Handbook for predicting slash weight of western conifers. Gen. Tech. Rep. INT-37. Ogden. UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 35 p.

Burgan, Robert E.; Rothermel, R. C. 1984. BEHAVE: fire behavior prediction and fuel modeling system--FUEL subsystem. Gen. Tech. Rep. INT-167. Ogden, UT: Intermountain Research Station, Forest Service, U.S. Department of Agriculture; 126 p.

Chase, Carolyn H. 1984. Spotting distance from wind-driven surface fires--extensions of equations for pocket calculators. Res. Note INT-346. Ogden, UT: Intermountain Research Station, Forest Service, U.S. Department of Agriculture; 21 p.

Cohen, Jack D. 1986. Estimating fire behavior with FIRECAST: user's manual. Gen. Tech. Rep. PSW-90. Berkeley. CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 11 p.

Deeming, John E.; Burgan, Robert E.; Cohen, Jack D. 1977. The National Fire-Danger Rating System--1978. Gen. Tech. Rep. INT-39. Ogden. UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 63 p.

Frandsen, William H. 1980. Study plan: measuring the temperature and moisture profiles in duff resulting from ground fires. Unpublished paper supplied by author.

German, Stephen C. 1985. Initial Attack Management System (IAMS) information package. Unpublished draft supplied by author.

Lawson, B. D.; Stocks, B. J. ;Alexander, M. E.; Van Wagner, C. E. 1985. A system for predicting fire behavior in Canadian forests. In: Proceedings of the 8th Conference on Fire and Forest Meteorology SAF Publ. 85-04: 1985 April 29-May 2; Detroit MI Bethesda MD: Soc. Am. Foresters; 6-16.

Philpot, Charles W. [Letter to Station Director). 1985 November 17. 2 leaves. Located at: U.S. Department of Agriculture. Forest Service, Intermountain Research Station, Ogden, Utah.

Radloff, David L.; Yancik, Richard F.; Walters. Kenneth G. 1982. User's guide to the National. Fuel Appraisal Process. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station. Forest Service, U.S. Department of Agriculture: 41 p.

Rothermel, Richard C. 1972. A mathematical model for predicting fire spread in wildland fuels. Res. Pap. INT-115. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 40 p.

Rothermel, Richard C. 1983. How to predict the spread and intensity of forest and range fires. Gen. Tech. Rep. INT-143. Ogden. UT: Intermountain Research Station, Forest Service. U.S. Department of Agriculture; 161 p.

Sandberg. David. 1980. Duff reduction by prescribed underburning in Douglas-fir. Res. Pap. PNW-272. Portland. OR: Pacific Northwest Forest and Range Experiment Station. Forest Service, U.S. Department of Agriculture; 18 p.

Susott, Ronald A. 1981. Study plan: the relationship of forest fuel thermal behavior to fire behavior--a small-scale combustion experiment. Unpublished paper supplied by author.

U.S. Department of Agriculture, Forest Service. 1983. Fire Management Analysis and Planning Handbook 82.1.

U.S. Department of Agriculture, Forest Service. 1985. Mt. Hood National Forest. Field guide for appropriate suppression response, 1985.Wilson, Ralph A., Jr. [In press]. A theoretical basis for modeling

Van Wagner, C. E. 1977. Conditions for the start and spread of crown fire. Canadian Journal of Forest Research. 7)1): 23-34

Wilson, Ralph A., Jr. [In press]. A theoretical basis for modeling probability distributions of fire behavior. Res. Pap. Ogden. UT: Intermountain Forest and Range Experiment Station. Forest Service, U.S. Department of Agriculture.

Interactive Papers with International Focus

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

International Wildfire Emergencies: Management in the 21st Century[1]

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Abstract: The U.S. Government, through the U.S. Agency for International Development's Office of U.S. Foreign Disaster Assistance (OFDA), responds to a wide variety of disasters throughout the world every year. These disasters range from "slow-moving" events like prolonged drought or plagues of grasshoppers and locusts to "fast-moving" threats to human populations resulting from fires, hurricanes, earthquakes and volcanoes. Although disaster types vary considerably, there is a recurring theme of disaster assistance elements that constitutes a meaningful and effective response. Critically evaluating the "lessons learned" from recent responses to world-wide natural disasters will prepare the disaster management specialist to develop an improved international assistance program for the 21st century. Details of natural disasters, the response process and "lessons learned" are given and future developments that will strengthen disaster assistance are discussed. A case example of the 1987 wildfires in southern Argentina illustrates disaster management requirements and needs.

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The U.S. Congress made its first foreign aid appropriation in 1812, when $50,000 worth of food and other supplies were delivered to victims of a massive earthquake in Venezuela (U.S. Agency for Int. Dev. 1984). But it wasn't until 1964 that the need for one central office to coordinate all U.S. Government (USG) assistance was identified. In that year the U.S. Agency for International Development (USAID) named its first Disaster Relief Coordinator. It is the Office of U.S. Foreign Disaster Assistance (OFDA) in USAID that coordinates the USG response to foreign disasters. As mandated by Congress. OFDA provides assistance not only for international disaster relief and rehabilitation, but also for disaster preparedness, early warning and mitigation. The Director of OFDA reports directly to the USAID Administrator, who is the President's special coordinator for international disaster assistance. OFDA's three geographic divisions--Africa and Europe. Asia and the Pacific, and Latin America and the Caribbean--provide country-specific expertise to respond to relief and preparedness needs in each region. OFDA also has an Operations Support Division which is responsible for coordinating relief activities during a major disaster. This Division is staffed by an Assistant Director, Fiscal Officer, Logistics Officer, Medical Officer, and Administrative Officer.

OFDA responds to requests for emergency assistance in an average of 37 disasters a year and monitors another 40 situations which could become disasters (USAID 1983). When disaster strikes, OFDA mobilizes USG resources and coordinates the USG response with that of voluntary agencies, international organizations, and other donors. To rapidly deliver emergency relief to the disaster site, OFDA maintains stockpiles of disaster supplies at five regional locations worldwide. The beneficiaries of this relief are primarily those in developing countries who are least able to survive without outside assistance.

Although disaster types vary from slow-moving events like prolonged drought to fast-moving threats like fires and hurricanes, there is a recurring theme of disaster assistance elements that constitutes a meaningful and effective response. A critical evaluation of the "lessons learned" from recent responses to world-wide natural disasters will prepare the disaster management specialist to develop an improved international assistance program for the 21st century. The "lessons learned" from past responses will be reviewed and recommendations will be made to strengthen disaster assistance in the future.

NATURAL DISASTERS AND THE RESPONSE PROCESS

Fiscal year 1985 was one of the worst years in OFDA's history in terms of the number of people killed and affected by disasters (USAID 1985). Drought and famine ravaged two-thirds of the African continent, causing the deaths of hundreds of thousands of people and threatening the lives of millions more. The world's worst industrial accident occurred in the town of Bhopal, India, when toxic gas leaked from a pesticide manufacturing plant and killed an estimated 2500 people. In Mexico, two high-magnitude earthquakes caused billions of dollars worth of property damage and claimed the lives of thousands. Table 1 summarizes the number of people killed by declared disasters for the 6 year period from 1980 through 1985. These data reveal that drought-induced famine, earthquakes, and severe storms have posed the greatest threat to human populations in recent times.

Includes data on all non-U.S. disasters to which the USG provided assistance. Source: OFDA 1985.

Other types of natural disasters have included volcanic eruptions, floods, and wildfires. OFDA also has provided assistance when people's lives were threatened by accidental or person-caused catastrophes, such as toxic waste spills, fires, explosions, air crashes, or civil strife. One of the more insidious recent natural disasters was the sudden, catastrophic release of gas from Lake Nyos on August 21, 1986, that caused the deaths of about 1700 people and 3000 cattle in the northwest area of Cameroon, West Africa (Kling and others 1987). Evidence collected at the disaster site indicated that the bulk of the gas released was carbon dioxide stored in the lake's hypolimnion and that the victims exposed to the gas cloud died of carbon dioxide asphyxiation.

Although OFDA has provided assistance to wildfire disasters in Argentina. Australia, Costa Rica, Dominican Republic, Ecuador, and Italy since 1983, it is clear from past data that other types of disasters pose a more prevalent threat to human populations. A May 1987 wildfire in northeastern China, however, has added a new perspective regarding the serious impact forest fires may have on human lives, property, and natural resources. This fire reportedly has burned more than 1 million acres, killed about 200 people, damaged 12,000 houses, and forced over 60,000 people to evacuate their homes--obviously a disaster of major proportions! Fires at the wildland-urban interface have been striking the international homefront in increasing numbers recently. For example, the Ash Wednesday Fire disaster in 1983 burned more than 840,000 acres of urban, forested, and pastoral lands in Victoria and South Australia, killing 77 people, injuring 3500, and destroying 2528 homes (Tokle and

Table 1--Number of people killed by declared disasters (FY 1980-85)

Disaster Type	FY80	FY81	FY82	FY83	FY84	FY85
Accidents	113	38	60	46	0	1,889
Droughts	N/A	N/A	N/A	N/A	N/A	403,000
Earthquakes	469	7,660	30	1,758	1,621	8,962
Epidemics	485	853	655	N/A	N/A	2,284
Floods	51	1,490	2,477	1,820	256	9
Severe Storms	338	113	209	542	1,489	10,929
Volcanic Eruptions	0	0	130	N/A	N/A	0
Total	1,456	10,154	3,551	4,166	3,376	427,073

Marker 1987). A new international focus on wildfire prevention and preparedness programs clearly will be a high priority to reduce the threat of fires to people, property, natural resources, and agriculture.

Once OFDA has been notified that a formal disaster has been declared by the Ambassador, it will immediately provide funding and guidance to the U.S. Ambassador or the U.S. Mission. Following a disaster declaration, OFDA approval is required for any assistance or expenditure over $25,000. Based on needs identified by OFDA-funded assessment teams and other available information. OFDA furnishes relief in the form of technical specialists, commodities, services, or transportation. OFDA can usually deliver relief supplies in 24 to 72 hours after the disaster strikes from its five stockpiles located around the world. Commodities may either be granted or loaned, and the host government is urged to recover and maintain reuseable items, such as tents.

International Disaster Assistance funds also may be used for rehabilitation during a 90 day period, which begins as soon as plans are developed and funds become available. The rehabilitation period does not extend beyond 90-days unless approved by the director of OFDA. Rehabilitation provides material and technical assistance towards restoration of essential community facilities and services, including shelter, water supply, sanitation, agriculture, and health. Short term rehabilitation efforts are not intended to supplement long-term development or technical assistance projects.

DISASTER ASSISTANCE SUPPORT PROGRAM

Since the early 1980's there have been increasing cooperative efforts between OFDA and the Forest Service, U.S. Department of Agriculture (USDA). The cooperation has included wildfire assistance in the Dominican Republic, on the Galapagos Islands and in Costa Rica. Emergency personnel were dispatched to the earthquake disaster site in Mexico City in 1985. The Forest Service also has administered three OFDA-funded Spanish-speaking fire suppression course for Latin America since 1983. This cooperation between OFDA and the Forest Service was formalized in August 1985, when a Resources Support Services Agreement between USAID and USDA's Office of International Cooperation and Development established a Disaster Assistance Support Program (DASP) within International Forestry of the Forest Service. DASP is funded by OFDA and provides that office with disaster prevention, preparedness, technical assistance, and emergency relief support. Program objectives include:

1. Provides support in prevention. preparedness, and operational planning for natural resources-related disasters.
2. Strengthens disaster planning and training for OFDA, U.S. Embassies/USAID missions and host countries.
3. Provides OFDA with the capability to identify and access natural disaster related technical experts and disaster management specialists.
4. Assists in the planning and coordination of workshops, conferences, studies, and publications that promote effective disaster prevention, disaster preparedness, and disaster management.
5. Augments the disaster relief efforts of OFDA. U.S. Embassies/USAID Missions, and host countries with technical experts and disaster management specialists on a short-term basis.

DASP consists of a Program Manager, Disaster Management Specialist, and a Program Secretary based in Washington, D.C. The DASP staff develops an annual plan of work to achieve OFDA's objectives in prevention, preparedness, technical assistance, training and disaster relief. Project activities are accomplished by DASP staff and other specialists who are recruited for short term assignments in the United States or overseas. In addition to Forest Service personnel, recent assignments have included representatives from the Bureau of Land Management, National Park Service and National Weather Service. Other agencies, consultants, private individuals and companies, and university personnel with disaster management experience also may be recruited for assignments.

As the objectives indicate, DASP may provide individuals to OFDA for technical assistance or emergency assignments. Because time generally is not a critical factor in notifying people for technical assistance assignments, these are filled through normal administrative channels. An operating plan, however, has been prepared to define the emergency response process whereby decisions are made and individuals are mobilized quickly to assist OFDA on international disasters. Roles and responsibilities must be clearly understood so that the right people are informed in a timely, manner, insuring an effective, efficient response (fig. 1).

After a formal request for emergency assistance has been received by DASP from OFDA, DASP prepares a situation assessment report that includes a summary of the personnel, equipment, and supplies being requested. This assessment is transmitted to Fire and Aviation Management, who contacts the Deputy Chief for State and Private Forestry. Once the Deputy Chief determines that the Forest Service will respond to the emergency request, OFDA and the Boise Interagency Fire Center (BIFC) communicate directly on resource orders. Mobilization of personnel, equipment, and supplies is accomplished through BIFC using established incident mobilization procedures. Identifying personnel to respond to an international emergency is accomplished from a disaster management skill file (roster), fire qualification red card system, pre-identified teams, or a selection based on requested skills.

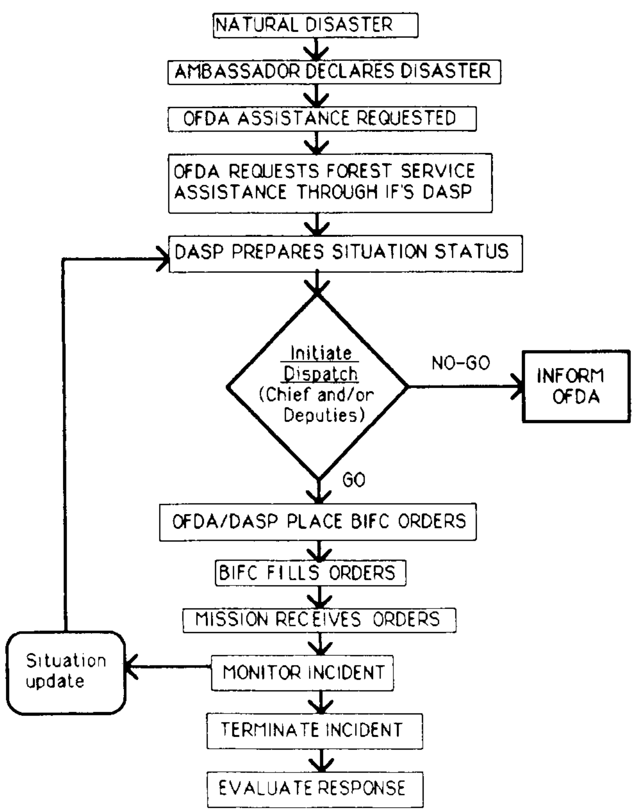

Figure 1--Stages of Forest Service assistance in an international disaster.

1987 ARGENTINA WILDFIRES

Especially dry conditions in southern Argentina in early 1987 established a severe wildfire situation along the foothills of the Andes between 39° and 42° south latitude. The general weather pattern leading up to the Lanin and Lago Puelo Fires was characterized by an absence of precipitation, temperatures that ranged from 85-95° F, and 30-50 mph maximum winds from the south, southwest, and west (Perkins and Benavidez 1987). The priority fire was the one at Lago Puelo, since it threatened isolated houses, a tract of commercial forest, and the small villages of Lago Puelo and El Hoyo.

The Lago Puelo Fire started on January 11, 1987, from an escaped campfire. The fire was within the jurisdiction of the National Forest Service and had burned approximately 10,000 acres by January 26. The Lanin Fire, under the jurisdiction of the National Park Service, reportedly was started by poachers on January 2, 1987, and immediately became a large, difficult fire. By January 27 this fire also was over 10,000 acres in size.

Due to the serious situation, the Government of Argentina requested U.S. assistance through the American Embassy in Buenos Aires on January 21, 1987. Upon receiving this request from the Embassy, OFDA asked DASP to provide a two-person wildfire team to advise Argentina officials and to provide an assessment on the fire situation to OFDA. The two individuals sent to Argentina were Jay Perkins, Klamath National Forest, California, and Gary Benavidez, Aviation and Fire Management, Southwestern Region of the Forest Service. Both individuals have been instructors at the International Fire Suppression Courses in Latin America since 1983. A briefing at OFDA in Washington, D.C., on January 23 prior to the team's departure included the following assessment objectives:

1. Size up situation and provide close technical consultation, advice, and assistance to agencies and organizations in Argentina to immediately help them in doing their job more effectively.

2. Prepare a situation status report on fire activity.

3. Evaluate adequacy of fire communication network.

4. Assess effectiveness of current air operations and determine future air operations needs.

5. Evaluate fireline and public safety situations.

6. Recommend appropriate types of technical assistance or equipment to U.S. Embassy and OFDA.

7. Evaluate the applied results of previous Latin American fire training courses as they related to suppression actions in Argentina at the time (several course graduates were in overhead positions on the wildfires).

The assessment by Perkins and Benavidez (1987) concluded that although a local "Fire Management Presuppression Plan" was in place when the fires started, it did not adequately address required actions during a multiple fire situation. The lack of a regional or national mobilization plan precluded a rapid response to multiple fire starts. There also was a serious absence of trained people, with the deficiency most significant at the crew level. Communication equipment was minimal, fire equipment failures occurred, and the heavy hand tools were intended for agriculture purposes and not firefighting.

The U.S. Ambassador in Buenos Aires formally declared the fire situation a disaster on January 30 and requested assistance in the form of fire equipment from OFDA. Fire equipment ordered through the Boise Interagency Fire Center included handtools, backpack pumps. headlamps, Mark III pumps, and hose. The equipment order was shipped from Los Angeles to Buenos Aires by the Argentina commercial airline, arriving on February 2. Burning conditions remained very active throughout February, with new fires breaking out in the vicinity of the town of Bariloche. The assessment team's specific long term recommendations will be covered under "lessons learned."

LESSONS LEARNED

OFDA responds to an extremely diverse array of disasters every year. Although disaster types vary considerably, there is a recurring theme of disaster assistance elements that constitutes a meaningful and effective response. Carefully evaluating the "lessons learned" from recent responses to world-wide disasters will better prepare the disaster management specialist to develop an improved international assistance program for the next century. Whether responding to an earthquake, severe storm, or forest fire, many common elements must be implemented to provide a timely and effective disaster relief effort. Lessons learned and recommendations from the October 10, 1986, earthquake response in El Salvador and two recent wildfire assessments in Argentina provide a basis for changes in international disaster assistance programs towards the year 2000 and beyond.

Two strong earthquakes struck the capital city of San Salvador in El Salvador on October 10. 1986. The first tremor registered 5.4 on the Richter Scale at 11:49 a.m. local time and was centered about 10 miles northwest of the capital. The second tremor registered 4.5 at 12:04 p.m. in the same vicinity. The earthquakes were felt in the neighboring countries of Honduras and Guatemala.

Major damage was centered primarily in a 20-square block area in downtown San Salvador. Major structural damage also was reported southeast of the capital, including the residential neighborhoods of San Jacinto, San Marcos, Modelo. The quake killed approximately 1000 people, injured an estimated 10,000 people, and left about 150,000 people homeless. Government buildings, the U.S. Embassy, hospitals, schools, and houses suffered severe and extensive damage.

On October 10, 1986, OFDA convened a 24-hour El Salvador Earthquake Working Group to coordinate assistance for disaster victims in El Salvador. The State Department established a Task Force to respond to the needs of U.S. Embassy and USAID personnel in El Salvador.

OFDA dispatched the following personnel to assist with disaster assessment and search and rescue efforts:

1. Five member assessment team from Costa Rica.

2. Four dog teams plus coordinator from the east coast.

3. Post-incident stress expert from University of Maryland.

4. Five member rescue team from Metro Dade Fire Department. Florida.

On November 18, 1986, a "San Salvador Lessons Learned" meeting was held at the Office of U.S. Foreign Disaster Assistance, Washington, D.C., to:

1. Identify opportunities and issues related to the earthquake that occurred in El Salvador on October 10, 1986.

2. Recommend actions that will strengthen future search and rescue relief responses.

Participants at the meeting included on-site disaster assistance personnel and representatives of OFDA, Federal Emergency Management Agency, U.S. Department of Agriculture, and the National Association of Search and Rescue.

Participants identified 28 opportunities and issues that were grouped under four major headings. The major headings included mobilization, emergency management, incident support and training. Many of the same issues that were identified following the earthquake in Mexico City also became problems in San Salvador. The key opportunities and issues identified at the San Salvador meetings can be grouped in this manner:

Mobilization

- Provide advance briefings
- Dispatch sufficient personnel
- Pre-position support equipment for relief personnel
- Provide for the timely dispatch of personnel

Emergency Management

- Implement an emergency management system
- Provide a communication team
- Establish an effective demobilization process
- Help facilitate the relief efforts of international donors
- Fulfill public relations role at disaster site

Incident Support

- Develop a uniform for relief personnel
- Dispatch communication equipment (satellite system and radios)
- Provide adequate rescue equipment
- Inform Embassies/Missions of emergency roles and responsibilities

Training

- Identify and train people to implement an emergency management system
- Train Embassy/Mission personnel to make effective assessments of disasters
- Orient search dog handlers on OFDA policies and procedures

Most of these issues are self-explanatory, but a few require additional clarification. It is important that emergency relief personnel are well briefed on their assignments prior to undertaking disaster assistance actions. People will be better prepared to provide disaster assistance, if they are well informed and understand specific objectives of their response. Ideally, personnel should be briefed by OFDA prior to leaving the United States and again upon arriving in the host country.

The five issues listed under emergency management included implementation of an emergency management system, providing a communication team, establishing a demobilization process, facilitating relief efforts and fulfilling the public relations role at the disaster site. Carrying out the first issue, implementing an emergency management system, is the most direct way to assure that the other four issues also are resolved. When an emergency management system like the Incident Command System is activated, the functions of communications, demobilization, coordination, and public relations automatically are accommodated as integral parts of the system. So in addition to sending search and rescue teams and heavy rescue teams, it is also important to dispatch an emergency management team that has the ability to organize all of the planning, logistic, and operational requirements related to the disaster. This type of emergency management organization allows the search and rescue teams to concentrate primarily on finding survivors.

Wildfire recommendations for Argentina made by Roby and Partido (1985) and Perkins and Benavidez (1987) can also be grouped under the four major categories established at the San Salvador earthquake meeting:

Mobilization

- o Develop national and regional mobilization plans

Emergency Management

- o Improve overall effectiveness of emergency management organizations

Incident Support

- o Do not invest heavily in an air tanker program until there is a significant increase in ground attack capability and better communications

- o Investigate opportunities to implement a helicopter program to transport people, equipment, and water
- o Continue to strengthen roles and responsibilities of National Coordination Committee
- • Acquire and deploy firefighting equipment at strategic locations
- • Develop a fire weather forecasting capability
- • Develop a basic fire danger rating system
- • Implement a fire prevention program through schools and the media
- • Consider using a single engine aircraft for fire detection patrols during periods of very high and extreme fire danger

Training

- • Produce training programs for basic firefighters and crew bosses
- • Develop a natural fire management seminar for decision makers
- • Furnish opportunities for specialized on-the-job fire training for selected individuals in the United States
- • Develop a prescribed fire training course for hazard reduction

DISASTER MANAGEMENT IN THE 21ST CENTURY

Elements of an appropriate disaster response include early warning of a pending problem, identifying the right respondents, mobilizing rapidly, making thorough briefings, providing accurate and complete assessments, implementing an effective emergency management system, establishing clear lines of communication for voice and data, providing humanitarian assistance, supporting disaster personnel, monitoring relief efforts, demobilizing personnel in an orderly manner, and evaluating results. We know what needs to be done, but what should the disaster response of the 21st century look like? What is our vision of a meaningful and effective disaster assistance program in terms of mobilization, emergency management, incident support, and training? As we highlight the future of these four areas, we recognize that prevention and preparedness measures will assume increasing prominence. Simply making a reflex response to a disaster will no longer be adequate.

Mobilization

Pre-identified specialty teams with the necessary training, equipment, language skills, immunizations, and passports for immediate mobilization to the disaster site have become common in the next century. Emergency management, communications, water purification, and fire management assessment teams are fully prepared for a dispatch within 24 hours or less. These teams are culturally sensitive to local conditions, allowing them to work effectively with host country counterparts.

In addition to these pre-identified teams, a computer based skills file, or roster, is used to quickly identify the right individuals with the technical expertise, language capability, and experience to fulfill a variety of technical assistance or disaster management requests. The roster, with thousands of individual entries, is comprised of applicants from federal, state, and local agencies, consultants, private individuals, and universities who possess in-depth international assistance capabilities.

By the year 2000 disaster management specialists are provided more detailed briefings prior to dispatch through such technologies as telecommunications, satellite weather data, and remote sensing imagery. In this manner specialists are prepared in advance to better understand conditions that prevail at the disaster site, contributing to more thorough and comprehensive assessments. The technology is available today to transfer a large variety of information to the disaster management specialist, even for remote parts of the world. For example, the Joint Agricultural Weather Facility (JAWF), a cooperative effort between the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of Agriculture, focuses on weather anomalies and their effects on the crop yield potential in major international crop areas (Moths and Heddinghaus 1986). Since JAWF can monitor and evaluate near-real-time operational weather data from the global station network, as well as satellite-derived meteorological data, the meteorological assessments can be just as available for fire purposes. Weather observations and analyses were provided by JAWF for forest fires in Argentina, China and Guatemala in early 1987. Others are investigating opportunities today to relay video images of natural disasters to experts at other locations for early evaluations. What remains to be done is the meaningful integration of all remote sensing capabilities into a comprehensive and coordinated system.

Emergency Management

In addition to dispatching search and rescue teams to the disaster site, it also has become a standard operating procedure in the 21st century to send an all risk emergency management team to organize the planning, logistic, and operational requirements related to the disaster. Besides allowing search and rescue teams to concentrate primarily on finding survivors, staffing an emergency management organization helps accomplish such key functions as communications, planning strategy and tactics of the response, facilitating other assistance, public relations, and demobilization. A leadership role may have to be assumed initially to demonstrate by example to the international community the important advantages of establishing an emergency management system at the disaster site comprised of trained and experienced emergency management specialists. Ideally the emergency management organization is staffed by specialists representing both the host country and international donors.

Incident Support

OFDA presently receives early warnings from several agencies regarding potentially serious natural threats to human populations around the world. NOAA monitors drought conditions that can contribute to food shortages, hunger, and famine. An earthquake monitoring network is tracked by the U.S. Geological Survey. Severe storm monitoring is conducted by the U.S. Navy, National Aeronautical and Space Administration, and NOAA. Provisions also have been made for tsunami warning and volcano monitoring.

An early warning system for international wildfires has not been as readily available. For example, a series of large wildfires totaling almost 11 million acres occurred in Borneo and Kalimantan in 1982 and 1983. These major fires were not "discovered" by the rest of the world until months later. After the turn of the next century a remotely sensed international fire danger rating system provides an index to potential burning conditions anywhere in the world. This information coupled with real-time imagery of emerging fires furnishes the disaster management specialist with new insights about pending problem areas. New advances are realized in fire prevention programs as well, since countries are better able to coordinate prevention efforts and messages with the new system for measuring fire danger potential.

Direct support to the disaster management specialist at the disaster site includes the latest advances in voice, data, and video communications. Portable satellite communication and telecommunication systems commonly are used for assessment, decisionmaking, information, and relief ordering purposes. The two-way electronic transfer of data, pictures, and hard copies provides a level of rapid and accurate information not previously available. The specialist also is the recipient of individualized support equipment that makes the relief assignment safer, more efficient, and more productive.

Training

OFDA has supported and funded an international fire suppression course for Latin America since 1983. The course, taught entirely in Spanish by Latin American, Spanish, and U.S. instructors, was designed to teach basic fire suppression skills and reduce the threat of wildfires to people, property, and natural resources. Secondary benefits have included a new spirit of self reliance as countries later have sponsored their own courses; and new expressions of international cooperation have occurred within the region on wildfires. For example, Chile sent 58 trained and equipped firefighters to help neighboring Argentina during that country's wildfire emergency in February 1987. That type of response, the first of its kind in the history of the two countries, was facilitated by the friendship and cooperation that grew out of the international fire courses. OFDA now is supporting a similar "train the trainers" bushfire suppression course in Ghana in West Africa that is scheduled for November 1987. This pilot program hopefully will serve as a precedent setting mechanism for fire training on the regional level in Africa as well. There also have been several successful examples where fire service personnel from other countries have been integrated within on-the-job training assignments with U.S. crews. This is a means of providing valuable and practical follow-up to the classroom experience.

The design, development, and implementation of an emergency management course for participants worldwide has similar positive implications for the future of disaster relief efforts. The course will use emergency management principles, case examples, and simulations to improve the coordination and management of disaster relief efforts. This training opportunity will be shared among U.S. participants, host country counterparts, and other international donors. Such training needs to be designed with sufficient cultural sensitivity so that training results may be readily assimilated and applied.

The 21st century also will see increasing opportunities for prescribed fire training that prepares people to minimize future disasters by skillfully using fire to reduce wildland fuel hazards in priority areas. Such training can help improve the in-country understanding of the relationship of fire management to ecological and environmental principles, as well as to fire protection and economic issues. An expanded effort should be made to translate more publications, training materials, and fire safety brochures to augment all training programs.

The training needs of U.S. personnel should be identified to improve international response capabilities and language abilities.

CONCLUSIONS

The data base of disaster statistics (OFDA 1985) makes it painfully obvious that no society in the world is exempt from the threat of person caused or natural disasters. Prevention, preparedness, disaster relief, and rehabilitation measures must be integral parts of a disaster management program aimed at minimizing the effects of disasters and reducing human suffering. In assessing the lessons learned from recent disasters, we have stratified recommendations in terms of mobilization, emergency management, incident support, and training requirements. The future of these four areas was highlighted to help prepare the disaster management specialist to develop an improved international assistance program for the 21st century.

Implementing the changes embodied in the lessons learned will strengthen OFDA's and host countries' capabilities in mobilization. emergency management. incident support, and training. But the fact remains that disasters know no timetable and one could occur tomorrow. It is important to translate the lessons learned and recommendations into action plans that implement feasible alternatives in a timely manner. We know the types of improvements needed today--the year 2000 could be too late for many people.

REFERENCES

Kling, George W.; Clark, Michael A.; Compton, Harry R.; and others. 1987.
The 1986 Lake Nyos Gas Disaster in Cameroon, West Africa. Science 236: 169-175.

Motha, Raymond P.: Heddinghaus, Thomas R. 1986. The Joint Agricultural Weather Facilty's Operational Assessment Program. Bulletin of the American Meteorological Society 67(9): 1114-1122.

Office of U.S. Foreign Disaster Assistance. 1985. Disaster History: Significant Data on Major Disasters Worldwide 1900-1985. Washington, DC: Office of U.S. Foreign Disaster Assistance.

Perkins, James H.; Benavidez, Gary V. 1987. Argentina. January 22-February 4, 1987, Lago Puelo and Lanin Fire Assessment. Washington DC: U.S. Department of Agriculture, Forest Service; 32 p.

Roby, George; Partido, Bob. 1985. Assessment of the Wildfire Situation in Argentina. Washington DC: U.S. Department of Agriculture, Forest Service; 34 p.

Tokle, Gary 0.; Marker, John. 1987. Wildfire Strikes Home! Laughlin, Jerry; Page. Cynthia, eds. National Wildland/Urban Fire Protection Conference, Boston, MA. U.S. Department of Agriculture, Forest Service; National Fire Protection Association: U.S. Fire Administration; 89 p.

U.S. Agency for International Development. Office of U.S. Foreign Disaster Assistance. 1983. Annual report FY 1983. Washington, DC. 132 p.

U.S. Agency for International Development, Office of U.S. Foreign Disaster Assistance. 1984. Annual report FY 1984. Washington, DC. 95 p.

U.S. Agency for International Development. Office of U.S. Foreign Disaster Assistance. 1985. Annual report FY 1985. Washington, DC. 141 p.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Wildfires and Forest Development in Tropical and Subtropical Asia: Outlook for the Year 2000[1]

Johann G. Goldammer[2]

Abstract: Growing population and enhanced demand for fuelwood, timber and agricultural land are causing a rapid deforestation process throughout the tropics and subtropics. This pressure on the forest land is being accompanied by increasing occurrence of human-caused wildfires. In most cases the fires are following in the wake of the exploitation of natural forests and the slash-and-burn shifting agriculture, or they are set deliberately by graziers, hunters and collectors of minor forest products. It is estimated that each year wildfires affect more than 50 million hectares of forested land and about 600 million hectares of savannah and bush land within the tropical and subtropical regions of the world. An increasing tendency towards wildfire occurrence can be expected during the next decades. The collective scenario in the remaining noncommercial forest land will therefore be characterized by degraded and open formations, and the overall development of many forest communities will lead to an extended transformation into highly flammable fire climax savannas. Examples of this process are given by describing the development of the most prevailing forest types in tropical and subtropical Asia. Relevant concepts of future wildland fire management and research need to be oriented towards this future scenario.

The tropical forests of the Americas, Africa and Asia in 1980 covered about 1,935 x 10^6 ha of which 61,200 x 10^6 ha were closed forest and 735 x 10^6 ha were open tree formations. In addition, fallow forest land accounted for 410 x 10^6 ha (FAO 1985). In most countries of the humid and dry tropics, forests are being cleared or degraded at a rapid rate, mainly to satisfy the basic subsistence needs of poor rural communities.

In this zone live 2 billion people, and the population is increasing at a net annual average rate of 2.6 percent. The increasing population is exerting pressure for the use of forest land for agricultural and settlement purposes. According to the estimates of the Food and Agriculture Organization of the United Nations (FAO 1985) the deforestation rate of closed tropical forests and open tree formations has been estimated at 11.3 x 10^6 ha per year during the early 1980's, mostly due to transfer of forest land to agricultural use.

Official statistics of deforestation in tropical Asia show an average deforestation of 1.8 x 10^6 ha per year during the 1976-80 period (FAO/UNEP 1981). The deforestation within Insular Southeast Asia alone (Indonesia, Malaysia, The Philippines) amounts to 0.8 x 10^6 ha per year, and is expected to reach 1.0 x 10^6 ha per year during the 1981-85 period.

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A great part of this forest depletion is due to shifting agriculture (slash-and-burn techniques) and the long-term effects of repeated and uncontrolled wildfires which accompany fuelwood collection, grazing and the harvest of minor forest products. The high frequency of wildfires in degraded vegetation types (savannas, bush and grasslands) is a major impediment to the restoration of former forest types or the development of climax forest (Goldammer 1986a). It has been estimated that the total area burned or cleared (all ecosystems worldwide) amounts to 630-690 x 10^6 ha per year (Crutzen and others. 1979; Seiler and Crutzen 1980). More than 98 percent of the burned and cleared area is in the tropics and subtropics. The total forested area cleared and burned annually for agricultural purposes in the 6 tropics covers about 30-80 x 10^6 ha. with an average of about 50 x 10^6 ha. The burning of savanna and bushland amounts to approximately 600 x 10^6 ha per year. Major single wildfires recently reported within the tropics sometimes exceed 3-5 x 10^6 ha (Malingreau and others 1985; Goldammer 1986).

SOCIOECONOMIC AND CULTURAL BACKGROUND

The vast majority of wildfires follows in the wake of traditional agricultural practices and other deep-rooted burning habits of the rural population. Goldammer (1986c) classified five broad causes of wildfires within the tropics:

Shifting Cultivation--Slash-and-burn agriculture is variously known as swidden, shag, kaingin, jhum, chena, podu, etc. in various parts of the world. It involves the clearing of woody vegetation by girdling and felling trees at the beginning of the dry season, and the burning of the dried biomass at the end of the dry season. The spread of the fires into the surrounding forest land is usually not controlled by the peasant forest cultivators. With increasing population pressure and due to shortening of fallow period, abandoned slash-and-burn areas are increasingly converted into sterile bush or stretches of grassland.

Grazing--Intentional grassland burning is an old cultural tool for stimulation of grass growth during the dry season, the control of parasites that carry and transmit stock diseases, control of undesirable plants, and driving of game. The scarcity of grassland available for grazing and a heavy reliance on grazing in forest areas results in extended uncontrolled silvopastoral practices, thus increasing the penetration and spread of grazing fires within the forested land.

Harvest and Collection of Nonwood Forest Products--Nonwood forest products have an increasing economic and social significance in many tropical countries. They include grasses, fruits, leaves, honey, wax, resin_ etc. The collection of this produce is very often facilitated by setting fire to the forest land. The permanent presence of people travelling through the forested land also provokes a high probability of accidental wildfires.

Migration and Land-Settlement Programs--The last undisturbed reserves of lowland tropical rain forests become more and more influenced by spontaneous migration and organized (public) land settlement projects. The ecological condition of the forests is altered by logging, fuelwood collections, and invasion of grasses, thus making the rain forest vulnerable to wildfires.

Wildland-Settlement Interface--The mutual influence of wildland and village/urban fires is considerably higher compared with that in industrialized countries outside the tropics. This is due to fuel characteristics, materials used for house construction, and burning habits of rural populations.

The role of natural (lightning) fires, which are considered a major factor in maintaining balance in the tree-bush-grass composition patterns of tropical savannas, becomes relatively less important compared with the increasing pressure of human-caused wildfires.

THE PRESENT SITUATION IN THE ASIAN THEATER

In accordance with the systematics of the FAO Asia Tropical Forest Resources Assessment (AFAO/UNEP 1981) this paper summarizes the wildfire information available for the whole of Asia south of China, from Pakistan to the west, to the island of New Guinea to the east, with the exception of the Maledives and Singapore (fig. 1). More than half of the land area of these countries is located within the tropical belt, except Bhutan, Nepal, and Pakistan, which are entirely above the Tropic of Cancer. They have been included because they are part of the same subcontinent and are presenting similar features as the neighboring regions of India. Moreover, tropical and subtropical climatic influences are perceptible quite north of the

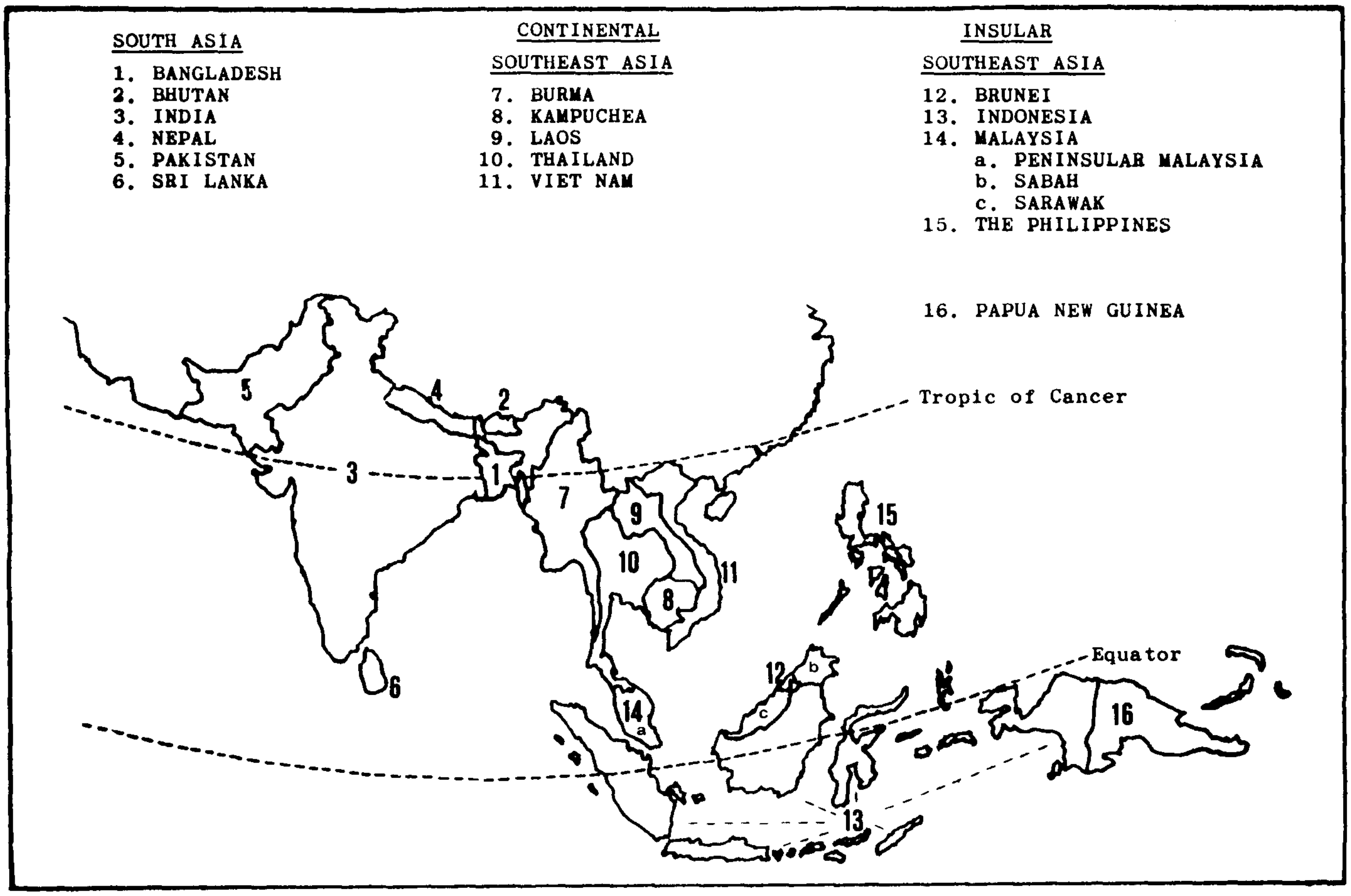

Figure 1--Sixteen countries were studied in tropical Asia.

Tropic of Cancer. Papua New Guinea, although generally considered an Oceanian country, has been included because of its relatively large area within the tropical belt and the fact that it shares with Indonesia the island of New Guinea.

The forest types regularly affected by fire are shown in table 1. Most of the field information was collected by the author. Information that was lacking has been taken from country reports or personal communication. In none of the countries reliable forest fire statistics exist. In most cases fire reports highly underestimate the real number, size, and damage of forest fires.

Some estimates may demonstrate the regional dimension of the forested area annually affected by fire. In India, Srivastava (1985) reports that almost one third of the Sal forest (Shorea robusta). one half of the hill pine forests (Pinus roxburghii) and one half of other forest ("miscellaneous") are burnt every year. Goldammer (1986) estimates that the annual area burnt in Burma may exceed 3.5 to 6.5 x 10^6 ha. Major single wildfires recently reported in Indonesia and Malaysia amounted to 2 to 3.5 x 10^6 ha. Altogether it is estimated that within tropical Asia more than 10 x 10^6 ha of forested land (closed and open broadleaved forests, and coniferous forests) are burnt over every year, in addition to the average deforestation rate of nearly 2 x 10^6 ha per year.

WILDFIRE REGIMES IN THE MAIN FOREST TYPES

The wildfire regime in tropical and subtropical forests is mainly determined by the degree and history of disturbance and degradation processes. The feature of a type of fire regime may be the same in different natural vegetation types. A broad classification of fire regimes in tropical and subtropical Asia

Table 1--Main forest types of tropical Asia regularly affected by wildfires. Bamboo forests and the different grass and brush savanna types are not listed because of regular fire occurrence throughout the whole region.

Country	Forest type regularly affected by wildfire[1]
Bangladesh	CBF 1,2.3: Dipterocarp forests in the Chittagong Hill Tracts. CBF 4: Shorea robusta forests ("inland Sal forest").
Bhutan	CBF 4: Shorea robusta, associated with Schima Walichii, Lagerstroemai, Terminalia spp. through the Sub-Himalayan tract, including lower slopes of the Himalayas. CF: Pinus roxburghii forest on Himalaya slopes between 1000 and 1500 m. associated with Rhododendron, Quercus and Castanopsis spp.
Brunei	Similar to Indonesia
Burma	CBF 4: Mixed deciduous forest with tea (Tectona grandis) Moist and dry mixed deciduous forest associated with bamboos (Bambusa, Dendrocalamus spp.) CBF 7: "Indaing" and "Semi-Indaing" forest with Dipterocarpus tuberculatus. CF 1: Subtropical hill forests with Pinus khesiya (1200 to 2400 m) and P. merkusii in lower elevations.
India	CBF 4: Tropical moist and dry Sal forests (Shorea robusta) and dry tropical teak forest ((T. grandis). CBF 9: Hill broadleaved forests with Quercus spp., being replaced by bamboos. OBF: With teak, sal, Terminalia, Anogeisus etc. CF 1: Pinus roxburghii (Western Himalayas), P. khesiya (eastern Himalyas). CF 2: Occasionally in higher elevations in Pinus wallichiana, Abies, Picea, Cedrus spp.
Indonesia	CBF: On periodically water-logged lands. CBF 6: Swamp and peat-swamp forest during extreme droughts. CBF 5: Dipterocarpaceae. CBF 1: With Shorea, Hopea, Dipterocarpus spp. OBF: Natural savannas with Melaleuca and Eucalyptus spp. in Nusatenggara and Irian Java. CF 1: Pinus merkusii in northern Sumatra (around Toba Lake).
Kampuchea	CBF: Melaleuca leucadendron forests. OBF: Mixed open forest with Shorea, Dipterocarpus, Terminalia spp. east of Mekong north of the lakes. CF 1: Hill pine forest west of Mekong (Pinus merkusii).
Laos	CBF 9: Broadleaved hill forest between 800 and 1000 m, with Fagaceae and Lauraceae. OBF 7: Dry deciduous forest in the Mekong lowlands, with Pentacme, Terminalia, Dipterocarpus, Shorea spp. In higher elevations Castanopsis, Quercus spp. CF: Pinus merkusii until 800 m, followed by P. khesiya.

Malaysia	Similar to Indonesia
Nepal	CBF 4: Sal forests (Shorea robusta) in the Terai lowlands. CF 1: Pinus roxburghii. CF 2: Occasionally in Abies, Picea and Tsuga stands.
Pakistan	CF1: Pinus roxburghii stands between 900 and 1650 m.
Papua New Guinea	OBF: Eucalyptus and Melaleuca savannas in south-central and southwest of the island.
The Philippines	CF 1: P. khesiya forest lands in the Central Cordillera of North Luzon. CBF: Occasionally in dipterocarp forests. Fire climax tree/grass savannas in the foothills of the Cordillera.
Sri Lanka	OBF: Mainly in monsoon grasslands and savannas.
Thailand	CBF 9: Extensive areas up to 1000 m elevation with Dipterocarpus, Shorea, Hopea, Anisoptera, Dalbergia and Lagerstroemia spp. CBF 4: Mixed deciduous forests with Tectona grandis. CBF 7/OBF 7/CF 1: Similar to Burma.
Viet Nam	OBF 7: Similar to Laos and Burma, especially in elevations above 500 m.

[1]Forest classification simplified on the base of Champion and Seth (1968) and FAO/UNEP (1981).

CBF = Closed broadleaved forest
OBF = Open broadleaved forest

1 = Tropical wet evergreen forest
2 = Tropical submontane or montane evergreen forest
3 = Tropical semi-evergreen forest
4 = Tropical moist deciduous forest
5 = Heath forest edaphic subtype
6 = Peat-swamp forest of moist forest
7 = Tropical dry deciduous forest
8 = Tropical dry evergreen forest
9 = Subtropical broadleaved hill forest

9CF = Coniferous forest
1 = Subtropical pine forest
2 = Himalayan moist temperate forest

therefore embraces different forest types of the classical forest distinction of Champion and Seth (1968) and the description by FAO/UNEP (1981). South Asia is represented by examples of India and Nepal. Continental Southeast Asia by Burma, and Insular Southeast Asia by Indonesia and the Philippines.

Tropical Wet Evergreen Forests

The tropical wet evergreen forests are found in regions with average temperature above 20°C and annual rainfall between 1,500 and 2,500 mm. The dry season does not extend beyond 2 to 4 months with less than 50 mm rainfall each. The forests occur mainly in Insular Southeast Asia. The dense overstory and the intermediate tree layer prohibit the entrance of sunlight and the establishment of an herb-shrub layer. Decomposition and nutrient cycling is rapid due to the humid climatic conditions. The tropical rain forest trees in general are fire sensitive due to the thin bark.

Under undisturbed conditions, these factors altogether characterized a nonflammable forest ecosystem. After being disturbed by logging operations, forest road construction and shifting cultivation, however, this forest type tends to become flammable due to increased sunlight and wind penetration, logging residues and understory formation (fig. 2). Pioneer plants which are often introduced from outside the region invade the forest land after serious disturbance of the rain forest. They form highly flammable vegetation covers (e.g. Eupatorium, Lantana and Imperata spp.).

An extreme and prolonged dry season may create conditions favorable to spread of extensive wildfires within this forest type. A striking example of this kind is the wildfire occurrence in the dipterocarp rain forest of Indonesia. Malaysia and the Philippines during the 1982-83 "El Niño" drought. After the 1982-83 fire season more than 3.5 x 10^6 ha of land was burnt in East Kalimantan/Indonesia, about the same area in Sabah and Sarawak/Malaysia, and about 20,000 ha in Mindanao/ Philippines (fig. 3). Even the peat-swamp forest, an edaphic subtype of tropical moist forests, were affected. The turflike accumulation of peat, which may be up to 20 m deep, was dried to a depth exceeding 0.5 m and carried ground fires causing the most severe and lasting damage of the rain forest (see also Lennertz and Panzeer 1984).

Such extreme environmental conditions usually occur only at long intervals. The fire

Figure 2--Slash-and-burn agriculture is one of the major fire causes within the tropical rain forest lands. Under extreme drought conditions the rain forest may become extremely flammable.

Figure 3--A burnt rain forest site south of Samarinda (East Kalimantan/Indonesia), 18 months after the 1982-83 wildfire.

occurrence in the moist tropical rain forests may therefore be restricted to such occasional events. However, increasing land-use pressure on the remaining closed rain forest areas in Asia will also increase the probability of coincidence of the factors mentioned causing such catastrophic wildfire situations.

Tropical Semi-Evergreen and Deciduous Forest

With longer dry periods, the evergreen forests are replaced by semi-evergreen and mixed deciduous forests. The shedding of leaves during the dry season favors the spread of surface fires within these forest types which are found throughout tropical Asia (fig. 4). Large expanses occur in Burma.

Fire presumably has played a major role in the successional development of the teak-bearing (Tectona grandis) mixed deciduous forests of Burma (fig. 5). None of the teak-bearing forests of Burma are primeval forest (Kermode 1964; Goldammer 1986d . All of them have been affected to some extent by wildfire. These fires usually burn as surface fires of moderate intensity. The main fuel components are the dry leaves of the fire-tolerant teak and other deciduous trees and the bamboos. A great part of the teak-bearing mixed deciduous forests has the characteristic properties of a fire climax forest (Goldammer 1986d). Exclusion of fire leads to a striking absence of reproduction of teak (U KYAW ZAN 1953; Goldammer 1986d).

The most important types of the deciduous dipterocarp forests are the "Indaing High Forest" and the "Semi-Indaing Forest" (fig. 6). They are also exposed to frequent and almost annual wildfires. The characteristic species are Dipterocarpus tuberculatus and Pentacme siamensis, which show the same fire-related surviving mechanisms as does teak. The long-term influence of these frequent fires is resulting in a slow process of site degradation and erosion. The total annually burnt area of forested land in Burma has been estimated at 3.5 to 6.5 x 10 ha (Goldammer 1986d).

In the northern part of the subcontinent of India the main deciduous forest type frequently exposed to wildfires is the "Terai" forest, predominantly consisting of almost pure or mixed stands of Shorea robusta ("Sal"). This dry dipterocarp forest association stretches south

Figure 4--Southern Tropical Dry Deciduous Forest, Chandrapur. Maharashtra/India. The degraded form of this forest type is characterized by wide-spaced fire tolerant species, e.g. teak (Tectona grandis).

Figure 5--Teak (Tectona grandis) a forestation near Haldwani (Uttar Pradsh/India). Surface fires generally occur during the end of the dry season and expose the mineral soil. The first monsoon rains hit the top soil layer before protective crown cover or herbaceous layer have been developed. This stand has lost approximately 2,000 m^3 of topsoil since stand establishment 30 years ago.

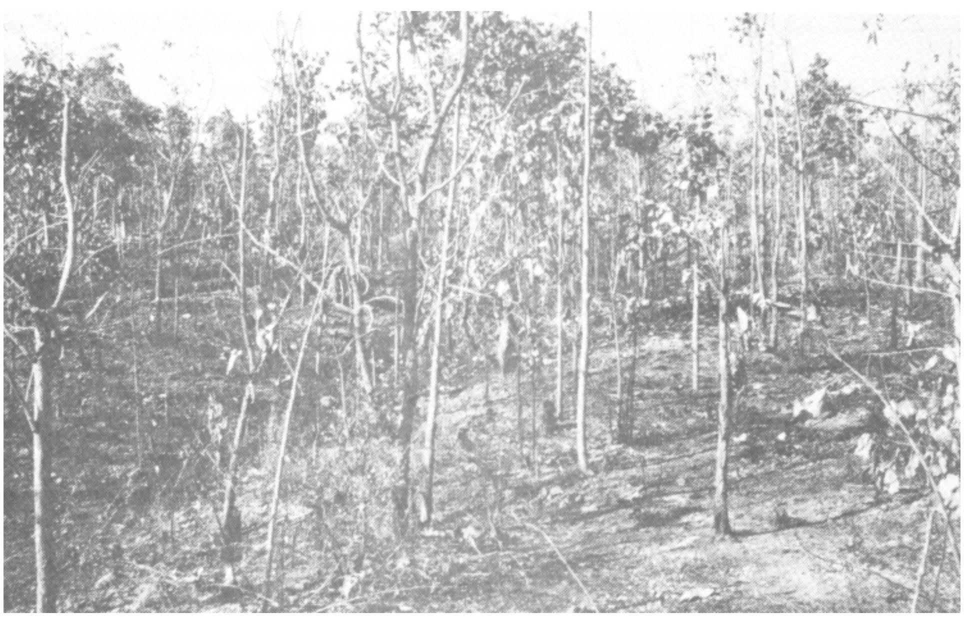

Figure 6--Lowland "Indaing" forest near Yezin, Burma. This forest type is subjected to annual fires, extensive grazing and fuelwood cutting. It represents a common feature of degraded deciduous forests within tropical South and continental Southeast Asia.

of the Himalayan foothills and is found in India, Nepal. and Bhutan. The frequent fires do not cause damage to the old Sal trees because of its thick and heat-insulating bark. Regeneration, however, is usually killed back. Since the rootstock is generally not affected by the low-intensity surface fires, new and vigorous shoots appear after the fire. These coppices are palatable for the local cattle, and the fires therefore are set deliberately.

A single fire will not harm this "fire tolerant" forest association. Frequent or annual fires, however, affect the age class distribution by widening the gap between the mature overstory and the regeneration process. Therefore, apparently overmature and decadent Sal forest completely lacking young trees occur in large areas (Goldammer 1986e).

The overall development of deciduous forests subjected to frequent wildfires, grazing and uncontrolled logging generally leads to degraded formations; the schematic development and the management implications are shown in figure 7.

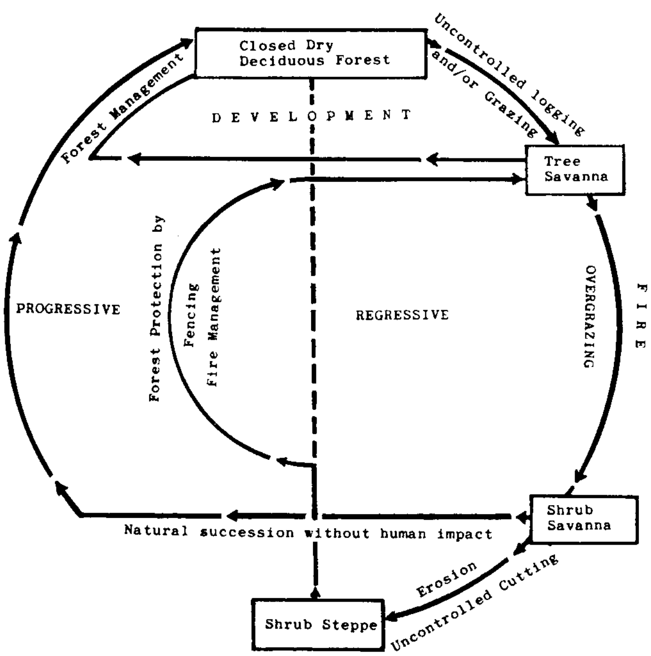

Figure 7--Schematic development and management implications of dry deciduous forest influenced by wildfires and grazing. (Modified after Verma 1972).

Broadleaved and Coniferous Hill and Montane Forests

Wildfire effects become increasingly visible throughout the submontane and montane forests of tropical Asia and the Himalayas. In mountainous regions where pines occur naturally (Pinus khesiya and P. merkusii in continental and insular Southeast Asia; P. roxburghii and P. wallichiana in the Himalayas), many of the broadleaved forests (e.g., dipterocarp forests in lower elevations and oak-chestnut associations in higher elevations) are replaced by fire-climax pine forests.

A striking example of this kind of forest development is found in the island of Luzon, the Philippines (KOWAL 1966; Goldammer 1985, 1987). Within the Central Cordillera the forest land has been influenced by human-caused fires for centuries. P. khesiya forms extensive, more or less even-aged stands which, at higher elevations above 1,500 m, maybe densely stocked but which become more open at lower altitudes (fig. 8). In most of the forests there are only two strata, the pine layer and the herbaceous layer dominated by fire tolerant grasses (Themeda triandra, Imperata cylindrica, Miscanthus sinensis) and bracken fern (Pteridium aquilinum). Fire exclusion leads to the reestablishment of fire sensitive understory and the replacement of a great part of the pines by dipterocarps (expanding from lower elevations) or oak associations ("mossy forest," descending from higher altitudes); under undisturbed conditions pure pine stands are usually restricted to dry sites and extremely poor soils, mainly on ridges and steep slopes.

Similar fire regimes and forest dynamics are observed within the whole natural range of Pinus khesiya (India, Burma, Thailand, Laos, Viet Nam). The same refers to Pinus merkusii, which occurs at lower elevations in both continental and insular Southeast Asia. Due to fire adaptation of P. merkusii the actual occurrence of this species has been greatly expanded compared with its natural (undisturbed) range (Lamprecht. 1986).

The stability of serial fire climax pine forests depends on a variety of factors (topography, fire frequency, distribution of precipitation, grazing/trampling effects, etc.). Steep slopes are generally exposed to erosion and long-term degradation whereas properly fire-managed stands may be maintained as steady-state pyroclimax forests.

Figure 8--Open and parklike Pinus kesiya hill forest stand in Burma. This type of fire-climax pine forest occurs throughout the whole range of Asian pine species.

Savannas and Other Forest Types

With increasing influence of uncontrolled logging, grazing and wildfires, most tropical forest types tend to follow the degradation scheme shown in figure 7. The overall development leads to wide-spaced vegetation covers, mostly referred to as tree, bush or grass savannas. Regardless of the primary origin of many of the diverse savanna types throughout the tropics, natural and anthropogenetic fires have long been recognized as the major factor in creating and maintaining tree-bush-grass composition patterns of tropical savannas (e.g., open dipterocarp woodlands throughout tropical Asia, or the temporarily inundated "Padang" heath forests of Indonesia).

Some of the pioneer plants occupying the forest land repeatedly cleared and burned (short rotation shifting agriculture) tend to form pure and highly flammable vegetation covers. The most aggressive invading grass species is Imperata cylindrica which forms extensive fields and most unsuitable habitats for germination and seedling growth of forested plants. These Imperata fields ("Cogonales" in the Philippines, "Alang-alang" in Indonesia) in 1970 covered more than 20 percent of the land area in the Philippines (6×10^6 ha). According to the latest data available, Imperata fields cover more than 16×10^6 ha in Indonesia, and 4×10^6 ha in Thailand and Papua New Guinea respectively (FAO/UNEP 1981), converting former forest land into almost sterile and unproductive waste land.

Frequently burnt forest sites may also develop into almost pure stands of broadleaved trees. Typical pyrogenetic forests are particularly common in Indonesia and New Guinea (Irian Java and Papua New Guinea). In Java gregariously growing Tectona grandis and Albizia lophanta stands are found. In New Guinea fire-induced Eucalyptus and Melaleuca savannas are common on sites exposed to seasonal inundation and extreme drought (fig. 9).

DESIGN OF A HOLISTIC SCENARIO

According to a report of The Population Institute the world's population has reached the 5 billion mark recently. It can be expected that the world's population will be growing to 6.2 billion by the year 2000 (Associated Press 1987). The countries facing the most serious growth by the end of this century are mainly

Figure 9--Industrial plantations within the tropics and the subtropics are mainly based on fast growing introduced species, e.g., Pinus and Eucalyptus spp. Stand development is characterized by extreme fuel build-up and wildfire hazard. Prescribed burning techniques need to be introduced into plantation management. Photo shows prescribed burning in 9-year old Slash pine (Pinus elliottii) plantation in Paraná/Brazil.

within the tropics and include Bangladesh, Brazil, Burma, China, Egypt, India, Indonesia, Iran, Kenya, South Korea, Mexico. Nigeria, Pakistan, the Philippines Tanzania, Thailand, Turkey, Viet Nam and Zaire.

This population growth will exert increasing pressure on the forest resources, causing the most serious changes within the tropical rain forest lands. Mabberley (1983) estimated that by 1990 there will be little of the rain forest left in Australia, Bangladesh, India, Sumatra and Sulawesi. peninsular Malaysia, Melanesia, the Philippines, Sri Lanka, Thailand, Viet Nam, Central America, Madagascar, and East and West Africa through the depredations of timber extraction, cattle ranching and transmigration schemes.

By the year 2000, it can be estimated that a great part of the forests within the tropics (except some of the remote and wet rain forest lands of Brazil's western Amazonia, the Guineas and the Zaire basin) will be degraded to secondary open forest land or converted to other land-use systems. In general the open forest lands will become more flammable, and the fire regimes will change accordingly. Forest and wildland dynamics and fire regimes will be characterized by increasing wildfire occurrence and increasing size of single fires. More frequent fires will lead to an overall selection of fire tolerant/resistant species, thus resulting in the loss of diversity in much of the previously closed forest land.

Rural land-use systems will be characterized by uncontrolled agroforestry techniques (agrosilviculture, silvopastoral techniques). The mutual interactions of fires spreading from agricultural land and villages into the wildland and vice-versa will increase the threat to human life and properties.

The direct local impact of wildfires on soil stability and erosion will have considerable downstream effects. Large-scale erosion, flooding, siltation and desertification will be more common. The forest denudation within the largest watershed of the world, the Himalayas, and its impact on the lowland south Asian countries may be a striking example of this kind of development (Koshoo 1986).

Furthermore the impact of biomass burning has a considerable potential in contributing to global changes of biogeochemical regimes and the atmosphere (see Crutzen and others 1979; Crutzen and Seiler 1980; National Research Council 1986; Palmer 1987).

IMPLICATIONS FOR MANAGEMENT AND RESEARCH

The lack of awareness of the wildfire problem within the tropics is mainly due to nonexisting or incomplete information about the extent and impact of wildfires. The existing reporting systems generally underestimate size and damage of the fires. Most information available is restricted to plantations.

In most tropical countries integrated forest/wildland fire management concepts need to be developed. These approaches will be extremely different from systems existing within the industrialized, mainly nontropical countries, because they will deal with a complete different socio-cultural, economic, and political background.

The need for tropical fire research is obvious. In Asia present activities are casual, and the research institutions and universities pay only small attention to the environmental impact of wildfires. However, some first programs were stimulated by FAD in the Philippines and in Burma (Goldammer 1986d, 1987). FAD has also initiated a series of local and national fire management programs in India, Indonesia, Burma and the Philippines. The next step should be a regional project within tropical Asia to stimulate and coordinate fire management activities.

If more information on fire ecology in tropical biota will be available, it presumably will be recognized that the overall tropical fire regime represents a threat to local and global natural resources, comparable to the emission-caused forest dieback within the industrialized countries of the northern hemisphere.

REFERENCES

Associated Press. 1987. Expert warns of population boom. The Stars and Stripes April 20. 4(col. 1-3).

Champion, H. J.; Seth. S. K. 1968. A revised survey of the forest types of India. Publ. Div. Gov. India, Delhi.

Crutzen, Paul J.; Heidt, Leroy E. ; Drasnec, Joseph P.; Pollock, Walter, H.; Seiler, Wolfgang. 1979. Biomass burning as a source of atmospheric gases. Nature 282: 253-256.

FAO/UNEP 1981. Tropical forest resources assessment. Forest resources of tropical Asia. UN 32/6. 1301-78-04, Tech. Rep. 3. Rome: FAD; 475 p.

Goldammer, Johann G. 1985. Multiple-use forest management, the Philippines. Forest fire management. FO: DP/PHI/77/011, Working Paper 17. Rome: FAO; 65 p.

Goldammer, Johann G. 1986a. Feuer und Waldentwicklung in den Tropen und Subropen. Freiburger Waldschutz Abhanklungen 6: 43-57.

Goldammer, Johann G. 1986b. Waldbrande and die Techniken ihrer Bekampfung. Umschau 86: 482-487.

Goldammer, Johann G. 1986c. Rural land-use and wildfires in the tropics. Agroforestry Systems (in press).

Goldammer, Johann G. 1986d. Technical and vocational forestry and forest industries training, Burma. Forest fire management. FO:DP/BUR/81/001, Tech. Note 5. Rome: FAO; 60 p.

Goldammer, Johann G. 1986e. A quick appraisal of the forest fire hazard in Nepal. Unpublished report. Kathmandu: FAO; 7 p.

Goldammer, Johann G. 1987. TCP assistance in forest fire management, the Philippines. Forest fire research. FO:TCP/PHI/66053 (T), Working Paper 1. Rome: FAO; 38 p.

Kermode, C. W. D. 1964. Some aspects of silviculture in Burma forests. Rangoon: For. Dep. Centr. Press; 162 p.

Koshoo, T. N. 1986. Environmental priorities in India and sustainable development. Ind. Sci. Congr. Ass. 73th Session. New Delhi, 224 p.

Kowal, Norman E. 1966. Shifting cultivation, fire, and pine forest in the Cordillera Central, Luzon, Philippines. Ecol. Monogr. 36:389-419.

Lamprecht, Hans. 1986. Waldbau in den Tropen. Hamburg: Parey; 318 p.

Lennertz, Ralf; Panzer, K. F. 1984. Preliminary assessment of the drought and the forest fire damage in Kalimantan Timur. Unpublished report. German Agency for Technical Cooperation (GTZ); 45 p. + Annex.

Mabberley, D. J. 1983. Tropical rain forest ecology. Glasgow: Blackie; 156 p.

Malingreau, J. P.; Stephens, G.; Fellows, L. 1985. Remote sensing of forest fires: Kalimantan and North Borneo in 1982-83. Ambio 14: 314-321.

National Research Council. 1986. Global change in the geosphere-bioshere. Initial priorities for an IGBP. Washington, Dc: National Academy Press; 91 p.

Palmer, Thomas Y. 1987. Tropical tropospheric temperature increases associated with birefringent carbon fractals. In: Proceedings 9th Conf. Fire and Forest Meteorology; 1987 April; San Diego, CA (in press).

Seiler, Wolfgang; Crutzen. Paul J. 1980. Estimates of gross and net fluxes of carbon between the biosphere and the atmosphere from biomass burning. Climatic Change 2: 207-247.

Srivastava, P. C. 1985. Work plan for the modern forest fire control, Utter Pradesh (1985-1990). Unpublished report. Haldwani; 203 p.

Verma, S. K. 1972. Observation sur L'ecologie des forets d'*Anogeissus pendula* Edgew. Bois et Forets des Tropiques, Nogent-sur-Marne, France.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Prescribed Fire and Fire Suppression Training in the U.S. Fish and Wildlife Service for the Year 2010[1]

James L. Murphy and Frank T. Cole[2]

Abstract: The Fish and Wildlife Service, U.S. Department of the Interior, uses prescribed fire for habitat improvement on over 400 National Wildlife Refuges across the United States. Wildfire is a problem on some refuges. Escaped fires have resulted in fatalities and the loss of millions of dollars in natural and man-made resources. The Service recognized the critical need for training in fire behavior, fire suppression and fire safety. A unique training and training development contract and program are described through which nearly 300 National Refuge System employees have been trained to safely carry out unique prescribed fire and fire suppression jobs. A cost savings of nearly $12,000 per trained employee may have resulted from this unique Service approach when compared with traditional training programs.

The U.S. Fish and Wildlife Service uses prescribed fire for hazard reduction, habitat enhancement, and food production on most of the 400 plus National Wildlife Refuges across the United States. Wildfire is a problem on some Refuges. Traditionally, refuge system personnel have had little or no formal training in wildland fire behavior, initial attack fire suppression, and fire safety.

Escaped prescribed fires over the last 10 years have resulted in fatalities and the loss of millions of dollars of natural and man-made resources. One escaped prescribed fire on a North Carolina Refuge that burned onto private land resulted in a series of lawsuits costing the Government nearly $3.5 million. The Service recognized the critical need for the development and presentation of training programs designed to help fire practitioner personnel understand and apply the principles and processes of wildland fire behavior, fire suppression and fire safety. Refuges could not always afford both the expense and the time off the job necessary for refuge personnel to complete the extensive series of suppression courses (S-courses) and other multiagency training available in some areas each year. Travel restrictions were increasing and training budgets were decreasing. The Service had very few people qualified to teach fire courses. Because of the unique nature of refuge locations, management objectives and problems, training had to be tailored to meet specific U.S. Fish and Wildlife Service needs.

TRAINING AND PROGRAM DEVELOPMENT BY CONTRACT

In 1984 the Service contracted the development and conducted the first series of courses to the Fire Science Systems Corporation (FSS)[3]. The FSS team responsible for the training development consisted of wildland fire

[1]Presented at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California

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[3]Mention of company name is for information only and does not imply endorsement by the sponsoring organizations.

specialists, a wildlife biologist and training specialists.

JOB AND TASK INVENTORY AND ANALYSIS

FSS Corporation specialists conducted an indepth analysis of jobs and component tasks of those jobs, which made up or should have made up. the Fire Management Function of the U.S. Fish and Wildlife Service.

The Inventory and analysis of jobs covered those performed by personnel permanently or only occasionally assigned to fire management jobs on Refuges within the National Refuge System.

The job and task inventory and analysis defined 19 discreet job requirements making up the Fire Management Function.

Each job was then broken down by:

1. Tasks making up that job.
2. Steps necessary to carry out and complete the tasks.
3. Standards for completing the task.
4. Conditions under which the jobs and task were to be performed.

The primary purpose of the job and task analysis was:

1. To identify the skills/knowledge requirements necessary to safely and effectively carry out jobs and tasks.
2. To define the training requirements of Refuge System personnel to perform effectively and safely their job assignments.

The Job and Task Inventory and Analysis served other purposes also: for example, aids to developing a Refuge fire management organization, job descriptions, performance evaluations, among others.

The job and task inventory and analysis indicated the priority needs for training existed at three levels:

Level I — Basic Prescribed Fire, Firefighting, and Fire Safety training.
Level II — Fire Supervisory ("Overhead") training.
Level III — Fire Management Specialist training.

The development of "Level I Training," a course titled "Basic Fire Management" was the principal goal of the contract and project.

SERVICE STEERING COMMITTEE

By October 1984, a Fish and Wildlife Service (FWS) Steering Committee on training development was formed. The Committee consisted of 10 members representing:

- FWS Washington Office
- FWS Fire Coordinator's Office located at the Boise Interagency Fire Center
- Regional Fire Management Coordinators
- Refuge Managers
- Refuge Fire Management Officers
- Training Branch, Bureau of Land Management, Boise Interagency Fire Center
- Fire Science Systems Corporation. Contractors

The first meeting was held at the Boise Interagency Fire Center in October 1984.

The main purpose of the meeting was to:

1. Review and recommend changes in "The Job and Task Inventory and Analysis of the Fire Management Function: prepared by the contractors.
2. Review the design of the new course, Basic Fire Management.

The Steering Committee gave the contractors the "go ahead" to finalize the first training session for the Klamath Basin National Wildlife Refuge in December 1984.

THE DESIGN OF BASIC FIRE MANAGEMENT TRAINING

Basic Fire Management was developed to meet a need for basic instruction in:

- Wildland Fire Behavior
- Planning and application of prescribed fire
- Basic initial attack fire suppression principles, strategies and tactics
- Initial attack
- Fire safety
- Team participation and operation
- Smoke management principles and techniques

Basic Fire Management was aimed at Refuge System personnel with little previous training who had some responsibilities for prescribed burning and for initial attack fire suppression.

The basic rationale underlying training requirements as defined by the Job and Task Inventory and Analysis and Refuge personnel is shown sequentially in Figure 1.

The structure of Basic Fire Management training is shown in Figure 2.

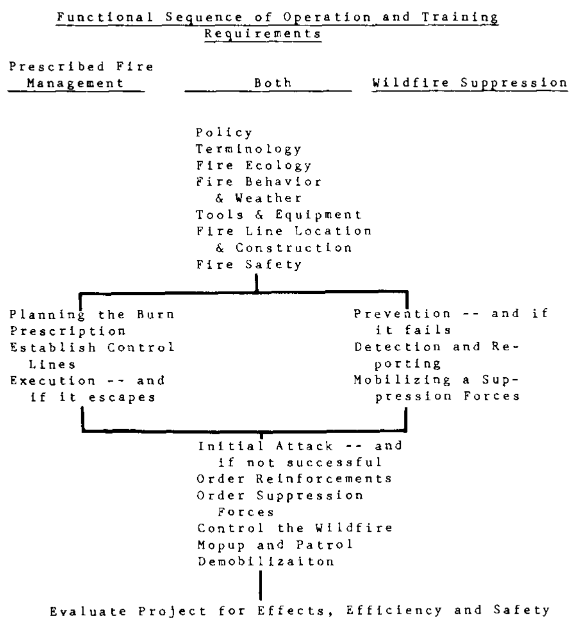

Figure 1--Relationship of Prescribed Fire and Wildfire

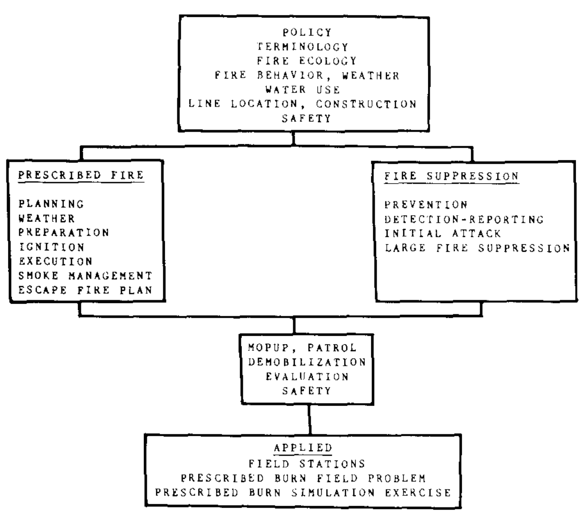

Figure 2--The Structure of Basic Fire Management Training

A series of subjects were identified which were basic and prerequisite to prescribed burning and fire suppression, e.g., fire behavior, and lesson plans for these subjects related to both specialty areas.

Another series of subjects were identified which had post-burn application to both specialty areas, e.g., mop-up and patrol, and lesson plans relating to both areas were developed.

The sequential flow of training emphasis is shown in Figure 3. In order to minimize time away from the job as well as travel and other costs, some 25-30 hours of prerequisite subjects were completed (with testing) at the student's home location. Prework assignments also served to bring students to a common level of technical knowledge and understanding.

An important segment of the 36 hour classroom session was the field follow-through. Students organized by teams were given hands-on instruction and practice in tool and equipment use and safety, weather and fire behavior measurements, fire safety including use of the fire shelter, helicopter safety, pumps and water delivery systems. Each student team also planned, prepared for, and carried out an actual prescribed burn and their performance was evaluated by the course instructors acting as coach/evaluators.

Training materials prepared for Basic Fire Management training included:

- Reference texts for all subjects - Lesson plans for all subjects
- Prework unit
- Visual aids, 35 mm slides

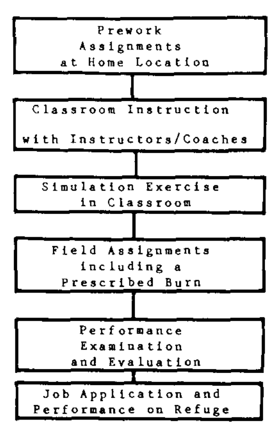

Figure 3--Sequential Flow of Training and Applications

- Student notebooks
- Instructor notebooks
- "How-to-do-it" handouts

SYNERGETIC EDUCATION

To make possible the equivalent of 140 hours of training in just 36 hours in the classroom, Fire Science Systems Corporation developed and copyrighted Synergetic Education, a system of principles, methods and techniques tailored to specific training courses to enhance the learning process and to make learning more fun and satisfying for the student. Some of the Synergetic Education processes applied to Basic Fire Management were:

1. Specially tailored prework assignments, and examinations done at student's home refuge.
2. "Hands-on" class and field exercises including a simulated and live prescribed burn.
3. Student teams with team leaders.
4. The Organization of course cadre trained as team coaches.
5. Dynamic team-cadre feedback processes applied several times a day for course quality and learning experience corrections.
6. Tutoring and evening sessions.
7. FWS instructor training and development.

THE PAYOFF TO THE U.S. FISH AND WILDLIFE SERVICE

Six course presentations were conducted nationally over the Refuge System by the FWS and the contractors during 1984, 1985 and 1986 with nearly 300 students attending.

The course was well received by the students right from the beginning. In fact there was no significant variation in Student Evaluation responses over all of the six courses. The average response percentage over all six course presentations is as follows:

Objectives met "extremely" or "quite well"
97 pct

Program well or precisely suited to ability to understand
85 pct

Presentations extremely or quite interesting
79 pct

Length of program about right: only a short or long
93 pct

Would recommend course to others
99 pct

The traditional course-by-course approach to Fire Training would have required 330-440 hours of training over a 2-3 year period per student. The cost would have been about $12.000 per student as calculated by the Training Branch, Bureau of Land Management, at the Boise Interagency Fire Center.

The Service's approach consisted of 20-30 hours of prework and 36 hours of class time which for the first time combined fire suppression and prescribed fire training with prerequisite technical subjects common to both. As a result of the tailored, integrated education system, the cost per student has been about $1,000.

The National Wildfire Coordinating Group (NWCG) requires a firefighter to have completed the courses S-190. Fire Behavior and S-130, Basic Firefighter. The Service's course, Basic Fire Management exceeds the requirements of these courses and includes significant portions of 12 other S-courses.

And there are some other benefits.

1. Thirteen instructors were trained both as instructors and coaches.
2. Team operation and supervisory/managerial skills were taught students. Refuge personnel learned the importance of team decision-making in fire operations, and that a qualified maintenance worker on a Refuge could be an incident Commander, supervising a Refuge Manager.
3. Safety awareness and how to apply safety principles on the job has resulted in few minor injuries and no serious injuries or fatalities during burn or fire suppression assignments.

SUMMARY

Because of budget and travel restrictions, National Refuge System personnel are authorized minimal time away from the job, and because of the unique locations and management objectives of Refuges, the U.S. Fish and Wildlife Service developed a unique Basic Fire Management training program.

Other Federal Agencies and State Agencies will be facing the same requirements and restrictions during the next 15 years and into the next century. The challenge will be to design training programs that minimize travel, time away from the job, expenses, satisfy the requirements of Fire Qualification Systems, and make use of creative training methodology which make possible the equivalent of at least 2 hours of skills acquisition for each hour spent in formal training sessions.

REFERENCE

Murphy, James L.; Steven, Gordon J. 1984. Job and task inventory and analysis of the fire management function of the U.S. Fish and Wildlife Service, 250 p., from U.S. Fish and Wildlife Service, August.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Laser Ignition Device and Its Application to Forestry, Fire and Land Management[1]

Michael D. Waterworth[2]

Abstract: A laser ignition device for controlled burning of forest logging slash has been developed and successfully tested. The device, which uses a kilowatt class carbon dioxide laser, operates at distances of 50 to 1500 meters. Acquisition and focus control are achieved by the use of a laser rangefinder and acquisition telescope. Additional uses for the device include back burning, selected undergrowth removal, safe ignition of oil spills, and deicing. A truck mounted version will be operational by fall 1987 and an airborne version by summer 1988.

A laser ignition device (LID), intended initially for the controlled burning of forest logging slash, has been developed and successfully tested, for this and a number of other applications. The device employs a kilowatt class carbon dioxide laser, the output of which is beam expanded and then focused to give a small, intense "spot" of heat at distances from approximately 50 to 1500 meters. Acquisition and precise focus control are achieved by the use of a laser rangefinder and acquisition telescope.

The device is fully steerable, can be ground based, airborne, or mounted on seacraft. Initially, the device will be truck mounted and will be operational by fall 1987. An airborne version should be available by summer 1988. Many additional uses to that originally envisaged have been determined. These include back burning, spot lightings, fire break generation, selected undergrowth removal, tree stand spacing, pruning and trimming (e.g. near power lines), the safe ignition of oil spills and slicks, land management, and deicing applications, for example, of television towers, aircraft and airport runways, snow drifts. In summary, the device has an application wherever concentrated, localized, safe, at a distance, heat is required. "Spot" concentration diameters of a few centimeters are obtained, even at the greatest focal distance of 1500 meters.

One major forestry application of the laser ignition device (LID) is the regeneration burning of "logging slash." Regeneration is the process by which the forest species harvested from a logging area (coupe) are replaced. To regenerate most forest types, or to establish new plantations, requires the use of hot fires set in fuels left on the ground after logging. The fires remove most of the fuel and prepare a suitable seed bed on which the new forest can be established. The controlled firing techniques aim to mimic nature's wildfire which originally produced much of the existing forests. Figure 1 shows a typical area ready for regeneration burning after logging, and Figure 2 shows an established regeneration burn.

Many lighting techniques already exist. These include hand held drip-torches, aerial and electrical incendiary devices, and gun-operated incendiaries. All of these techniques have access or safety problems or both. In recent years there have been a significant number of

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[1]Presented at the Symposium on Wildland Fire 2000. April 27-30, 1987, South Lake Tahoe, California.

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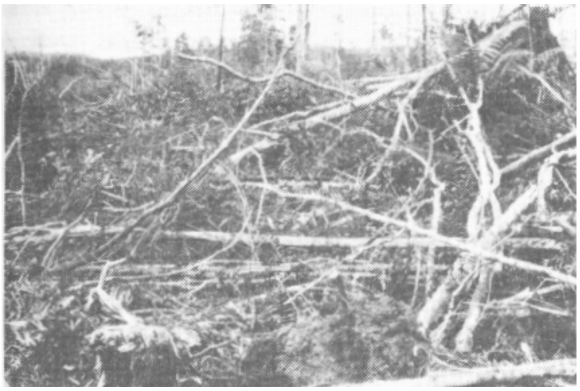

Figure 1--Typical area ready for regeneration burning after logging.

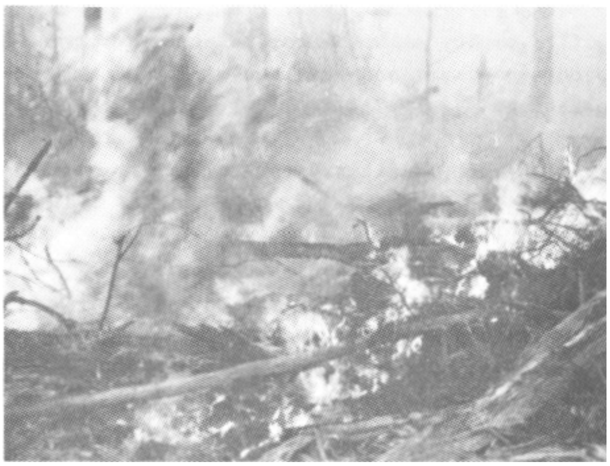

Figure 2--An established regeneration burn.

disasters and near disasters. Furthermore, many of these techniques are costly, from both the capital and the manpower aspects.

CONCEPT OF THE LASER IGNITION DEVICE

A laser device, employing suitable optical systems, which is "easily mobilized" and capable of igniting forest fuels at distances varying from 50 to 1500 meters from roadside vantage points, would satisfy the criteria of a safe and effective ignition facility. Other applications which have been mentioned in the introduction, follow almost automatically, e.g., oil spill ignition.

Other advantages, in addition to safety for all users and uses, and effectiveness in that success in application is guaranteed, include accessibility of fuel sites in difficult terrain, the ability of the device to be either ground based or airborne in helicopters or fixed winged aircraft, instant availability and rapid mobility. Furthermore, the device is self-contained and relatively compact, simple to operate, provides shorter burn times because of its high power density and ability to scan forest fire areas, and is cost effective in that it may be operated by one or at most two persons. Operating costs are thus limited to transport fuel costs, power generation costs (e.g., engine fuel for truck using power takeoffs for ground based operation) and operators' salaries. Capital costs are not insignificant, but based upon current, and foreseen, uses can be amortised within 5 to 7 years from a cost-effective point of view.

In selecting a suitable laser for this application, cognizance must be taken of

(i) availability and size of suitable "high power," CW or lasers, or both,
(ii) propagation properties of laser beams through the atmosphere,
(iii) means of controlling the plane of focus of the laser beam with "precision" to avoid unwanted and/or uncontrolled ignition.

With regard to (i), and taking into account (iii), the ideal laser system is a kilowatt class carbon dioxide laser operating at a wavelength of 10.6 micrometers in a continuous wave mode. These lasers usually operate close to TEM_{oo} mode with a gaussian output beam profile steeply peaked at the center. Typical output beam dimensions might be 10 millimeters 2 diameter to $1/e^2$ points, and 12-13 millimeters total width. Beam divergence is usually of the order of 1-2 milliradians, and it is worth noting that with such an unfocused laser beam, the beam diameter at 1 kilometer from the laser is in excess of 1 meter. Power densities greater than approximately 40 watts per square centimeter are required for rapid ignition of most cellulose materials so that such an unfocused laser beam is useless for this purpose. With the focusing system used here, power densities up to 10^4 watts per square centimeter are obtained. For optical reasons, it is advantageous to operate the laser in other than single mode, enabling an increase in energy output and a minimizing of losses caused by optical obstructions such as mirrors and so on. This operation is achievable with the laser system described here.

Alternatives to CO_2 lasers include Nd-YAG lasers operating at 1.06 micrometers in a multimode configuration. The main disadvantage with these is the shorter wavelength which reduces the energy absorbed by fuels for a given power density. As output power increases, beam divergence and hence other optical properties, such as minimum spot size, energy spillover, and so on increase also, making these lasers less attractive.

Point (ii) is of some significance vis-a-vis thermal blooming and the propagation of laser radiation through a turbulent atmosphere. Quite clearly, the longer the wavelength the less do these effects have on any laser beam. A turbulent atmosphere is normally caused by thermal gradients near ground level and by the effects of winds and so on. While this effect is significant at optical and near infra-red wavelengths, it becomes negligible at a wavelength of 10.6 micrometers over the ranges of interest here (see, for example, papers by Tatarsky 1960). Provided the energy densities along the path of propagation are small enough, thermal blooming will not present any problem either. For a kilowatt class CO_2 laser operating as proposed, thermal blooming may be completely neglected.

Perhaps the most critical area conceptually is point (iii). For propagation distances up to about 1500 meters, and laser powers in the kilowatt class, the limiting factor which determines the minimum obtainable spot size is Fraunhofer diffraction. For a diffraction limited spot, its diameter is given by

$$\frac{1.22\,\lambda}{(r/d)}$$

where λ = wavelength

r = radius of beam at output of projecting optics

d = distance to focus

The corresponding power density at focus is given by

$$P\,D = P_{out}\,\frac{4r^2}{\pi(1.22\lambda^2 d^2} = (0.855)\,\frac{r^2}{\lambda^2 d^2}\,P_{out},$$

where P_{out} is the laser output power

Note that this analysis applies only for a uniformly illuminated projection aperture, and requires modification to take into account, for example, a gaussian laser beam, optical obstructions, and so on.

Simple calculations show that a meter class projection aperture is required to achieve acceptable spot size at the focal distances of interest. This projection aperture, illuminated by, say, a 1 kilowatt laser, will produce power densities of 40 and 25,000 watts per square centimeter at focal distances of 1500 meters respectively.

To achieve this focal range, clearly some focusing optics, operating at 10.6 micrometers must be included, prior to the final projection aperture, to vary the output convergence angle. Two alternatives exist:

(1) employ a two mirror telescope as the projection system and vary the mirror separation;

(2) employ auxiliary optics and leave the mirrors fixed.

For a number of reasons, including mechanical difficulties in moving mirrors, and optical problems associated therewith, option (2) has been selected. This consists of two optical sub-systems which move relative to each other. By the careful control of the designs and movements of the optical sub-systems, diffraction limited spot sizes are obtained over the desired focal range.

A block diagram of the overall concept is shown in Figure 3, where the system has been represented essentially by three modules, the laser, the focusing optics, and the projection telescope.

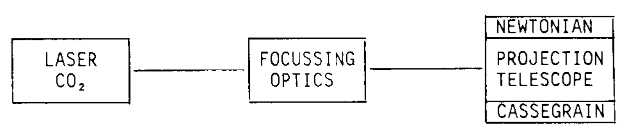

Figure 3--Block diagram of LID concept.

PRACTICAL CONSIDERATIONS

The previous section describes, in general terms, the principles of operation of the laser ignition device. Pertinent to its successful and safe operation is knowing precisely the distance to the target to be ignited. In forestry applications, focal distances are required to an accuracy of $\pm$ 2 meters at a distance of 1000 meters, to avoid ignition of material beyond predetermined boundaries. Similar tolerances will apply for the safe, exclusive ignition of other materials, such as oil slicks and oil spills, and for selected melting of snow drifts or ice.

For these reasons a laser rangefinder is employed to determine the distance to the target. The output of this is used to control the focus of the laser beam onto the target, and this is updated approximately every 3 seconds. Operation of the laser rangefinder and focusing mechanisms are fully automatic, with built-in calibrations and checks. Any thermal effects on the LID are automatically calibrated out upon command from an operator. Focal calibration at a very short distance (~ 10 M) is also available.

As mentioned above, the laser beam is projected onto target by means of a single mirror or two mirror telescope. The telescope is mounted on an altitude-azimuth support, both axes being driven by variable speed motors. Motions of $\pm$ 45 degrees in altitude and $\pm$ 180 degrees in azimuth are provided. In a typical operational mode, the device pans at a rate of approximately 0.5 m sec^{-1} at target. Faster or slower, including zero, speeds are also available, by use of a joystick control.

Acquisition of ignition sites is by means of an auxiliary optical telescope or television monitor, or both, located adjacent to the laser rangefinder. Once a site has been selected, the ignition is activated by a push button control on the joystick control hand paddle. Virtually instantaneous, ignition is obtained and in forestry applications firestorm conditions are obtained at the above mentioned panning rates.

TESTING OF LID

As early as 1980, a prototype LID was constructed and tested using a 200 watt carbon dioxide laser. Figure 4 illustrates schematically the arrangement used then with the 200 watt laser mounted beneath, but fixed to, the telescope. The test successfully demonstrated the principles of operation and confirmed theoretical predictions of spot sizes at given distances. However, due to

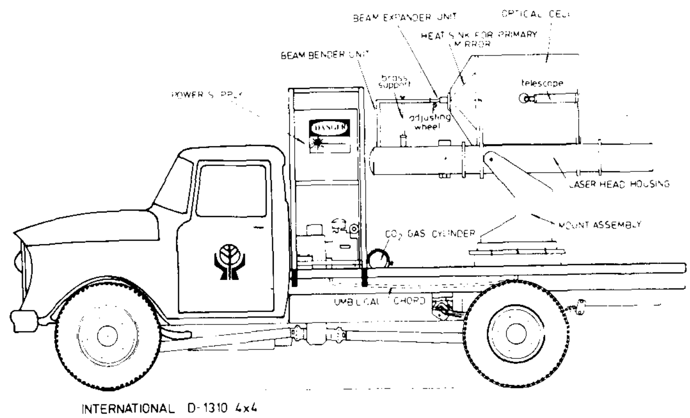

Figure 4--Schematic of first Laser Ignition Device on truck.

instabilities in the particular laser employed, sustained ignition of logging slash fuels was not consistently satisfactory.

Later, the initial LID system was modified to carry a Spectra-Physics 810 laser with an output power in excess of 500 watts. Tests carried out with this laser in 1985 were extremely successful from all points of view. Firestorm conditions were obtained with forest fuels, over a range of several hundreds of meters, including fuels of significantly different moisture content. Other types of fuels, e.g. plastics, synthetics, have been ignited successfully in the field. Ignition of additional materials, both in normal and adverse conditions caused by, for example, high winds, have been simulated in the laboratory using power densities and spot sizes obtained with the actual LID in the field. For example, the trimming of trees, ice-cutting, oil residue and oil slick ignition, have all been tested successfully.

The laser ignition device is now being manufactured on a commercial basis, arising from the very successful tests referred to above, and from the tremendous interest expressed in its potential in North America, Europe and Australia. As mentioned in introduction, a commercial version of the device, containing further improvements upon the above-mentioned prototypes, will be available for demonstration in the 1987 North American fall.

REFERENCES

Gebhardt, F.G.; Collins, S.A. 1969. Log-Amplitude Mean for Laser Beam Propagation in the Atmosphere. J.O.S.A., 59; 1139 p.

Gebhardt, F.G.; Smith. D.C.; Bauser, R.G.; Rohde, R.S. 1973. Turbulence Effects on Thermal Blooming. Applied Optics 12; 1794 p.

Lawson, D.I.; Simms, D.L. 1952. The Ignition of Wood by Radiation. Brit. J. Appl. Phys. 3; 288 p.

Tatarsky, V.I. 1961. Wave Propagation in a Turbulent Medium. New York: MacGraw Hill.

Thomas, P.H.; Bowes, P.C. 1961. Some Aspects of the Self-Heating and Ignition of Solid Cellulose Materials. Brit. J. Appl. Phys. 12; 222 p.

Waterworth, M.D.; Rolley, E.R. 1983. The Ignition of Logging Slash from Safe Distances using a CO_2 Laser. SPIE Publications 398.

Wood, R.M.; Taylor, R.J.; Rouse, R.I. 1975. Laser Damage in Optical Materials at 1.06. Optics and Laser Technology; June.

Gen. Tech. Rep. PSW-10l Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Wildland Fire Prevention: Today, Intuition--Tomorrow, Management[1]

Albert J. Simard and Linda R. Donoghue[2]

Abstract: Describes, from a historical perspective, methods used to characterize fire prevention problems and evaluate prevention programs and discusses past research efforts to bolster these analytical and management efforts. Highlights research on the sociological perspectives of the wildfire problem and on quantitative fire occurrence prediction and program evaluation systems. Focuses on current and future advances in fire prevention management due to research in four critical areas: modeling fire occurrence, measuring prevention effectiveness, measuring economic efficiency, and optimizing program mix.

YESTERDAY

Over the years, fire managers and researchers have developed a number of methods to characterize fire prevention problems and evaluate prevention programs. Perhaps their efforts began as far back as 1905 when, on the first Forest Service fire report form, field personnel documented the fire cause in addition to 14 other items of information (Donoghue 1982). Fire causes were, and continue to be, key elements in the development and analysis of fire prevention programs. First devised to pinpoint how fires started, fire-cause categories were later expanded to include persons responsible for wildfire ignitions.

These data, combined with other fire report information and summarized in tables and on charts and maps, have been used for decades to develop fire occurrence histories. Based on this information, for example, fire managers in North America know the temporal distribution of wildfires by the month, week, day, or hour (Haines and others 1975; Simard and others 1979). The major problem is that temporal fire occurrence distributions average many individual occurrence patterns, most of which are decidedly not average. Knowing what happened yesterday or last year provides little information about tomorrow or next year. Likewise, the same data disclose <u>where</u> fires occur, from a strategic scale (Simard 1975) to a management scale (Haines and others 1978) to a local scale (Meyer 1986). These data also indicate the types of fuels in which these fires burn (Haines and others 1975).

Although spatial and fire cause distributions are not constant over time, they are relatively conservative (particularly compared to weather) and, unlike temporal data, can provide many insights into the near future. From fire report data and consequent analyses, managers have been able to characterize their fire prevention problems, determine the actions needed to solve them, and allocate resources to implement their prevention programs.

These analytical and management efforts have been bolstered by research that developed along

[1]Presented at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

[2]Project Leader and Research Forester, respectively, North Central Forest Experiment Station, USDA Forest Service, East Lansing, Michigan.

two parallel tracks--one dealing with sociological perspectives of the wildfire problem and the other with quantitative fire-occurrence prediction and program evaluation systems. A major thrust of the sociological research over the years has been to develop demographic profiles of select subpopulations that differ significantly from the general public. The attitudes and characteristics of these groups (such as arsonists, hunters, children, and rural residents), their knowledge of fire, and/or their reasons for setting fires have been documented in numerous reports spanning four decades of research (e.g., Shea 1940; Kerr 1958; Folkman 1963; Siegelman and Folkman 1971; Bertrand and Baird 1975). One of the underlying objectives of this research was to supply managers with useful information about high-risk groups likely to start wildfires through carelessness, ignorance, or arson, thus providing a basis for developing effective fire prevention programs.

To a lesser extent, researchers also studied the attributes of fire prevention message sources as well as the characteristics and uses of prevention messages and channels of dissemination. Informal sources of fire prevention messages such as personal contactors and local opinion leaders in the rural South were characterized by several researchers (e.g., Dickerson and Bertrand 1969; Doolittle and others 1975; Doolittle 1979). The mass media, including television, radio, newspapers, signs, and billboards, were also recognized as primary sources of prevention information. Scientists studied how and when these media were used, their content, their ability to change attitudes, and their impact on message retention (e.g., Griessman and Bertrand 1967; Bernardi 1970; Doolittle and others 1976; Folkman 1973). By examining the sociological perspectives of the wildfire problem, these scientists have developed a fund of knowledge critical to designing effective fire prevention programs.

Other scientists have tried to develop fire occurrence forecasting and program evaluation systems that go beyond descriptive statistics and analyses. Nickey and Chapman (1979), for example, developed a probability model to evaluate the Red Flag Alert Program applied during periods of Santa Ana winds in Southern California. From estimates of the probability of human-caused fire occurrence and the conditional probability of fire size at suppression, they determined the expected suppression costs for a patrol area for any given day. By comparing expected suppression costs to actual costs, they calculated the Expected Monetary Value (EMV) or the "estimated gain" of added prevention efforts. There are no statistics, however, on the accuracy of their method when applied to localized areas on a daily basis.

Attacking the problem from a different perspective, Nickey (1980) described a method to quantitatively analyze fire occurrence using c control charts. This graphic method is used to determine whether changes in fire occurrence are due to chance or to changes in external factors such as weather or population. The method is founded on the Poisson distribution which provides a model of the expected number of wildfires within a given week. According to Nickey, control charts provide a way to quantitatively evaluate increasing or decreasing fire occurrence patterns over time, to forecast expected future fire occurrence under stable external conditions, to determine the effects of unusual weather conditions, and to evaluate the performance of fire prevention programs.

To "provide a definitional and conceptual framework for putting wildfire prevention management on a badly-needed logical foundation," J. M. Heineke and S. Weissenberger (1974) developed a stochastic model of human-caused ignitions that, together with their model for fire damages and decision costs, could be used to determine prevention decisions that minimize the expected value of fire prevention costs plus fire losses.

As Wetherill (1982) states so pointedly, however, despite all these research efforts and "the easily recognized benefits of program evaluation. . .logical, documented evaluation of the fire prevention programs of forestry agencies is seldom done. . .Prevention personnel are aware of the lack of evaluation methods, but are unsure how to go about evaluating a program without the sole reliance on fire occurrence statistics." Furthermore, he notes, "Fire occurrence alone is an inadequate indicator of prevention program value even though it is the most commonly used indicator. The vast judgmental gap between prevention activities and the benefits of those activities cannot be bridged by intuition alone. Why must forest fire prevention be unscientific when the rest of our forestry practices are governed by scientific principles? Evaluation is the key to unlocking this understanding." It is this alone that will take us from an era characterized by intuitive judgments and ad hoc decisionmaking into one of sound management shored by a strong foundation built on scientific principles and practices.

TODAY

The foundation of prevention management will be laid on four sequentially related cornerstones necessary for fire prevention program evaluation:

- modeling fire occurrence
- measuring prevention effectiveness
- measuring economic efficiency
- optimizing program mix.

In the 1980's, research has begun to tackle each of the above and early results are just beginning to emerge.

Modeling Fire Occurrence

The primary cause of the great temporal variability in fire occurrence is weather. It follows, therefore, that we must understand weather effects on fire occurrence--from daily prediction to annual normalization.

Weather Influences

Daily fire occurrence prediction and seasonal normalization can be tied to most fire-danger rating systems. For example, Lynham and Martell (1985) explained 47 percent of the variability of annual resident-caused fires in five regions of Ontario by using a daily prediction model (based on the Canadian Fine Fuel Moisture Code) and integrating the daily predictions over a season. Haines and others (1983) developed a similar model, using the Model G Ignition Component (IC-G) of the U.S. National Fire-Danger Rating System (NFDRS) (fig. 1). When integrated over a year, using seven Northeastern weather stations (each representing an area of 6,170 square kilometers), this model similarly explained 46 percent of the average annual variation in fire occurrence.

As the length of the integration period decreases, however, the amount of variability explained by simple predictors decreases markedly (fig. 2). In other words, the shorter the integration period, the more difficult the

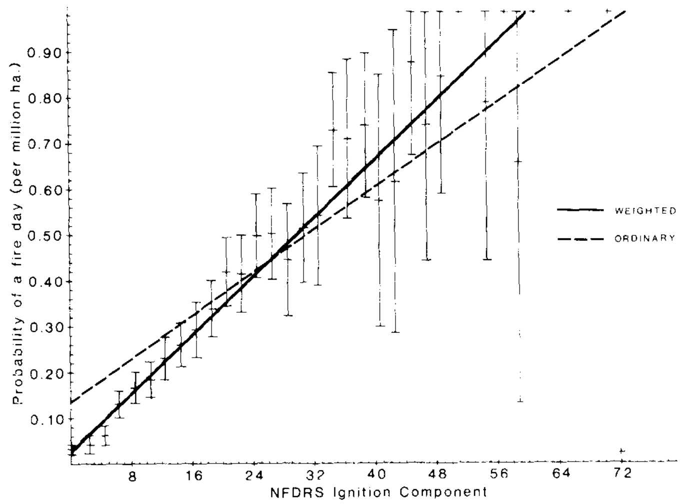

Figure 1--Probability of a fire day (per million hectares) vs. the NFDRS IC-G for grouped data. Horizontal bars represent the mid-point and 95 percent confidence limits for each group (Haines and others 1983).

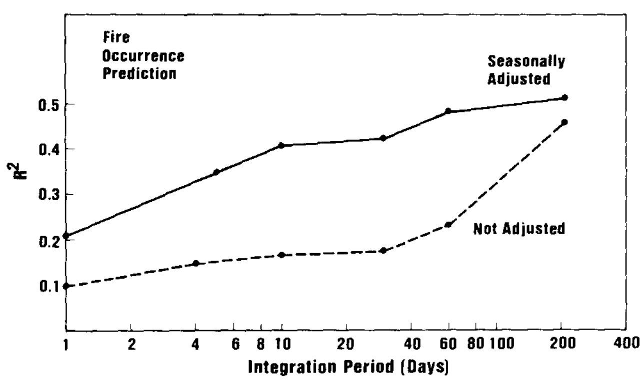

Figure 2--Percent of fire occurrence variability explained vs. length of integration period.

prediction. Specifically, only 10 percent of daily fire occurrence variability in the Northeastern U.S. is explained by IC-G. Although nonweather-related stochastic elements presumably play an increasingly important role at shorter time intervals (and for smaller areas), weather effects are also more complex. For example, failure to incorporate the bimodal eastern fire season significantly impacts daily fire-occurrence prediction. To overcome this deficiency, Lynham and Martell (1985) stratified the fire season into five sub-seasons. More recently, Martell added trigonometric regression to a logistic occurrence model to accomplish this purpose.[3] As part of a separate study, we normalized monthly occurrence per 100 units of IC-E (fig. 3) and adjusted the daily occurrence prediction model of Haines and others (1983) (fig. 2). This simple improvement doubled the explained daily variability to 21 percent. A more fundamental approach to fire seasons would be to model the controlling plant phenology process directly.

Kourtz (1984) employs a stochastic fire occurrence model developed by Cunningham and Martel (1973f). Five classes of the Canadian Fine Fuel Moisture Code, two seasons, and a historical data base are used to predict expected daily fire occurrence (Ward 1985). Occurrence probabilities (in thousandths of fires) are calculated for 20 x 30 kilometer grid cells (to coincide with standard base maps). The system employs "Bayesian analysis" of the historical data base. Essentially, for each day that observed fire occurrence departs from the historical trend, occurrence probabilities are gradually shifted upwards or downwards accordingly, thus giving greater weight to the most recent data. Such an analysis could be run annually or even monthly or weekly to monitor short-term changes in human-caused fire occurrence patterns. Statistical analysis of the original model indicates that it is a good predictor of annual fire occurrence over an 11,000 square kilometer district (Cunningham and Martell 1973); no data are available on daily accuracy within a 600 square kilometer cell.

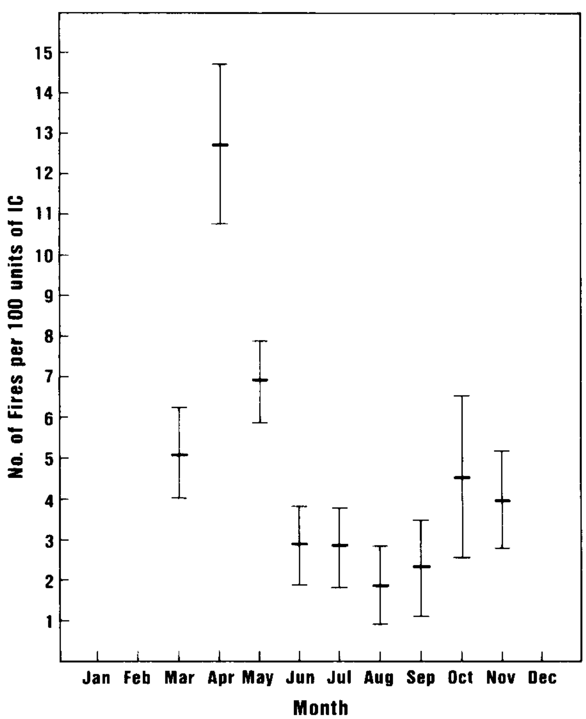

Figure 3--Monthly fire occurrence probability per 100 units of NFDRS IC-E.

When integrated over a year, most fire occurrence predictors are highly intercorrelated. High annual average values for a long-term component are normally associated with high average short-term component values. This is much less so for daily prediction, however. For example, adding a long-term (Palmer Z-Index) threshold to an NFDRS IC-O threshold provides a background signal that yields notable improvement in the discrimination power of a daily Extreme Fire Potential Index (fig. 4) (Simard and others 1987a). An ideal

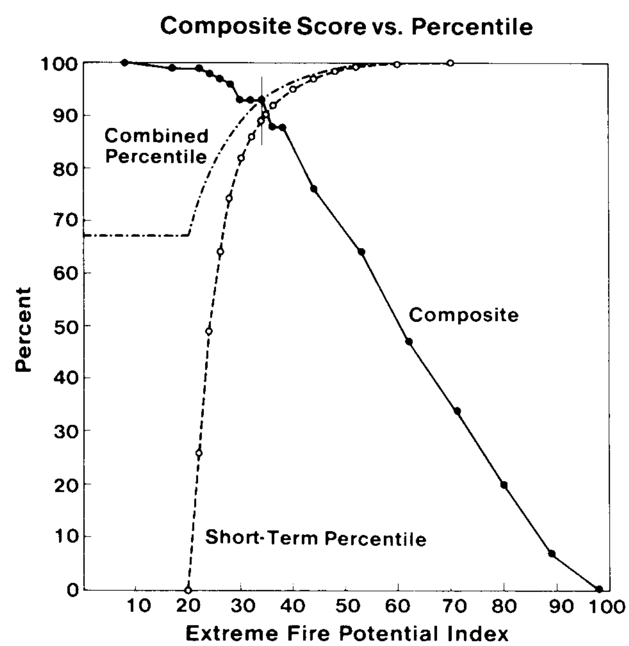

Figure 4--Percent of U.S. extreme fires identified (composite score) vs. Extreme Fire Potential Index (EFPI); percent of Northeastern U.S. days below EFPI threshold vs. EFPI (Simard and others 1987a).

[3]Unpublished data on file, University of Toronto; Forestry Faculty; Toronto, Ontario, Canada.

weather-driven daily fire occurrence model would incorporate short-, medium-, and long-term components as well as phenological and other seasonal adjustments.

There is also a class of global weather variables that show some promise for seasonal fire occurrence prediction in some regions. For example, by January 1, global meteorologists are able to predict the occurrence and strength of an El Niño during the coming year with some skill. Adding the January 1 state of the Quasi-Biennial Oscillation of the upper stratospheric zonal winds permits us to predict half of the variability of fire activity for the coming fire season in six Southern States (Simard and others 1987b).

Examined individually, these daily and seasonal fire occurrence prediction models are disjointed and fragmentary. They tend to be related to specific areas and are data-dependent. When seen as a whole, however, a pattern of increasing knowledge can be discerned. We are beginning to understand individual components of the weather-fire occurrence process and to aggregate individual results. Generally applicable weather-related daily fire occurrence prediction and seasonal weather normalization will surely be a reality before the year 2000.

Other Influences

In examining relationships between human-caused fires in the Eastern U.S. and nonprevention influences, Donoghue and Main (1985) found a strong latitude effect (fig. 5).

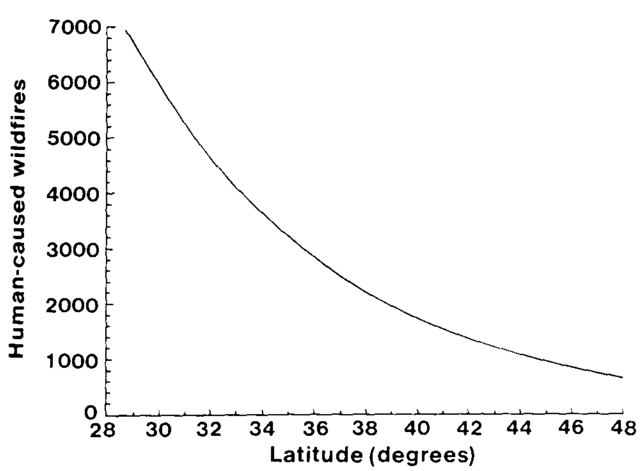

Figure 5--Number of human-caused wildfires in the Eastern U.S. vs. latitude (Donoghue and Main 1985).

In essence, as latitude increased from south to north, fire occurrence decreased. Latitude integrates several factors that can influence fire occurrence such as length of fire season, fuel types, and cultural attitudes towards fire. For example, because Southern States have longer fire seasons, there are more opportunities for fires to occur. As a corollary, the effect of a unit of prevention effort is diluted over a longer period, and should, therefore, have less impact on total fire occurrence. To test the former hypothesis, we normalized fire seasons for 27 Eastern National Forests by dividing fire activity[4] for each week by the highest weekly activity. We then defined the seasons as 10, 15, 20, and 25 percent of maximum activity but found that the results are independent of how the seasons are defined. Our investigation showed that latitude alone explains half of the variability in length of fire season in the Eastern U.S. (fig. 6).[5] Further investigations should yield additional measurable processes that can be used to more directly link latitude and fire occurrence.

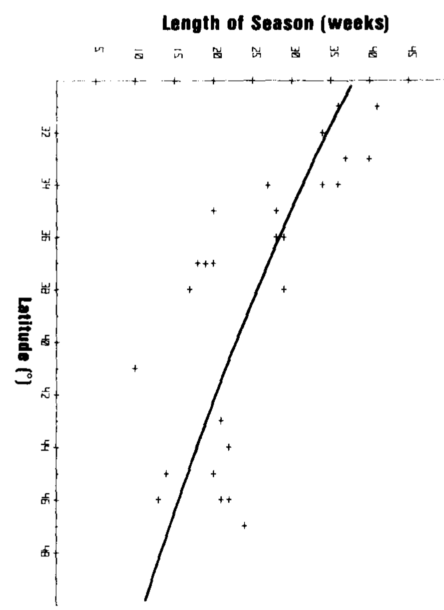

Figure 6--Number of weeks with fire activity greater than 10 percent of peak weekly activity vs. latitude.

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[4]Each Class A fire received 1 point, Class B=2, C=4, D=8, E=16, F=32 points.

[5]Unpublished data on file, North Central Forest Experiment Station, East Lansing, Michigan.

Donoghue and Main (1985) also found a weak (R^2 =0.08) but statistically significant ($P<0.001$) parabolic relation between average state nonmetropolitan population density and human-caused wildfires in the Eastern U.S. (fig. 7). At one end of the scale, the relative fraction of wildland has decreased sufficiently to reduce the risk that an ignition source will start a wildfire. At the other end, there are fewer people (hence, potential ignition sources)--again resulting in fewer wildland fires. Lynham and Martell (1985) found a similar relation for resident-caused fires in Ontario. We suspect that other demographic variables or attributes of the local economy, such as median income, unemployment rate, or types of industry, might also have merit in quantifying resident-caused wildland fires.

As with the weather component of fire occurrence, these are early, incomplete results. The methods show promise, however, that in the future we will be able to compensate for many of the nonprevention influences on fire occurrence. Eliminating such background "noise" will permit much more accurate measurements of prevention program effectiveness than are currently possible.

Measuring Prevention Effectiveness

Pottharst and Mar (1981) studied the effectiveness of engineering improvements in reducing railroad fires in the Pacific Northwest. After normalizing annual railroad fire occurrence for weather differences, they measured two attributes of prevention effectiveness--total impact and implementation rate. In 1969, the State of Washington mandated installation of spark arrestors on locomotives by April 1970. Results (fig. 8) indicated that within 2 years, exhaust fires were reduced by 95 percent. The State also required installation of improved braking systems in the early 1970's. The gradual decline in brake shoe fires (fig. 8) was attributed to a gradual replacement program. Overall, this modification reduced brake shoe fires by about 85 percent. Even with engineered improvements, however, fires cannot be completely eliminated. Malfunctions and maintenance (or lack of) can notably affect system efficacy. Pottharst and Mar (1981) found a similar overall effectiveness and decline rate for Oregon brake shoe fires, but exhaust fires were reduced much more gradually than those in Washington. This was attributed to Oregon's persuasive strategy vs. Washington's legal requirement. It is clear that, when cause-and-effect are directly linked and adequate data with minimal "noise" are gathered, a classic intervention study can reliably measure prevention effectiveness.

Outside the engineering field, cause-and-effect relationships are much more tenuous; many are unknown. The noise level in the data increases markedly. In such cases, a cross-sectional analysis is often more productive. Donoghue and Main (1985) used such an approach to examine the effectiveness of law enforcement in preventing arson fires. They

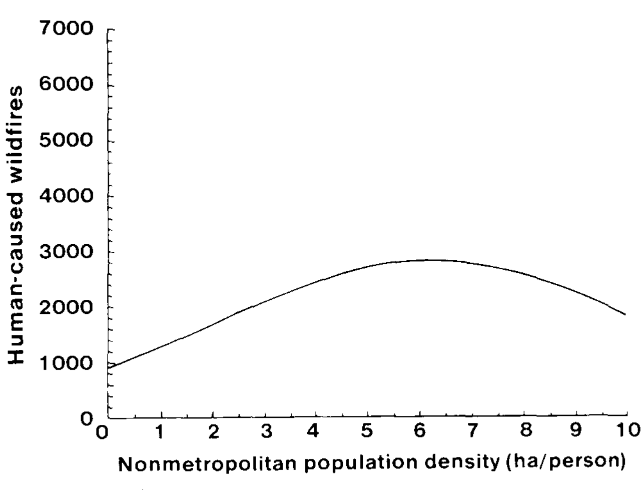

Figure 7--Number of human-caused wildfires in the Eastern U.S. vs. nonmetropolitan population density (Donoghue and Main 1985).

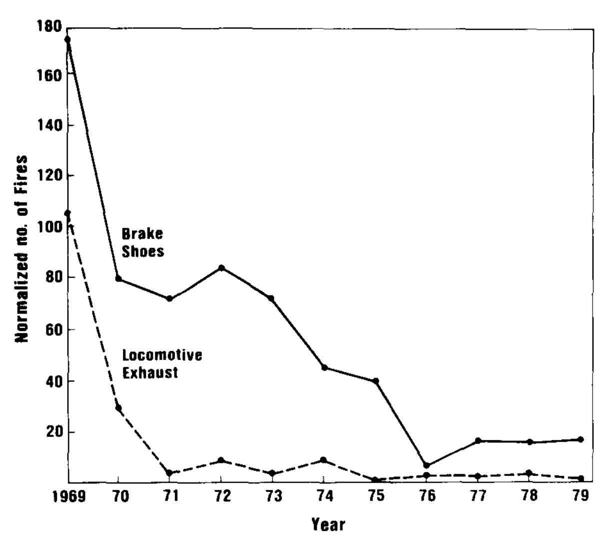

Figure 8--Number of railroad fires in Washington by year (data from Pottharst and Mar 1981).

collected data on the number of fire-related prosecutions, convictions, and settlements in 27 Eastern States during 1972-1981. They partially normalized fire occurrence based on latitude, monthly precipitation departures from normal, and nonmetropolitan population density.

They found that, although enforcement was not significantly related to all fires, it was significantly related to arson fires (fig. 9). Although the relation is weak (R^2 =0.04), the breadth of the data base, general consistency of results within individual States, and conformance with what would be expected lend credibility. At low enforcement levels, small changes yield large decreases in the number of arson fires. At higher levels, marginal productivity is notably less. Going from no law enforcement to a high level of enforcement reduces arson fire occurrence by about half (compared to an average of 90 percent for engineering improvements and railroad fires). Although only an exploratory study, these results indicate that it is possible to quantitatively link a sociological prevention activity to wildland fire occurrence, even though many of the causative pathways between them are ill-defined.

Measuring Economic Efficiency

Simply counting numbers of fires presents an incomplete evaluation of prevention programs. Ultimately, the cost of preventing fires must be compared with the savings of the fires that did not occur. Recently, Donoghue and others. (1987) adapted a four-quadrant fire economic model (Simard 1976) to fire prevention. They used a case study employing enforcement and arson fire data from Arkansas to demonstrate how the model could be applied. The model incorporates four functions (fig. 10). Quadrant I contains a loss function, defined by the relation between the number of fires and suppression cost plus net value change (CS + NVC). Quadrant II contains the previously described enforcement production function or the relation between units of enforcement and number of arson wildfires. Quadrant III contains the enforcement cost function or the relation between costs and units of enforcement. Quadrant IV contains a cost transform--in other words, a line that simply equates the two cost axes. Graphically, the nomogram facilitates transforming the enforcement cost function in Quadrant III to Quadrant I. Summing the two functions in Quadrant I yields the traditional least cost plus loss presentation (fig. 10).

Lacking detailed information, an average CS + NVC per fire was used in Quadrant I. An average cost per unit of enforcement was similarly used in Quadrant III. The enforcement production function for the Eastern States was

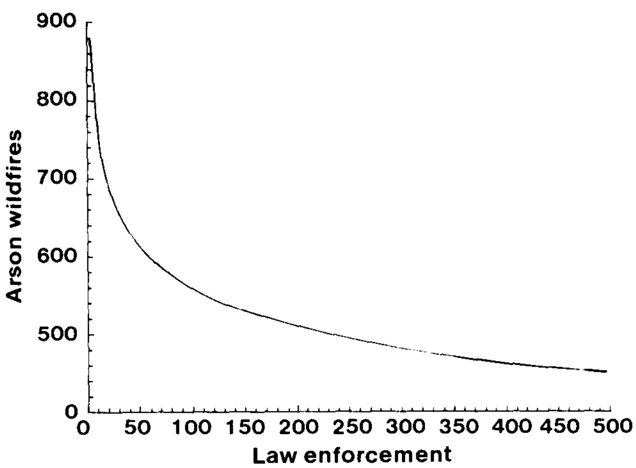

Figure 9--Number of arson fires per State vs. level of law enforcement (sum of prosecutions + convictions + settlements) in the Eastern U.S. (Donoghue and Main 1985).

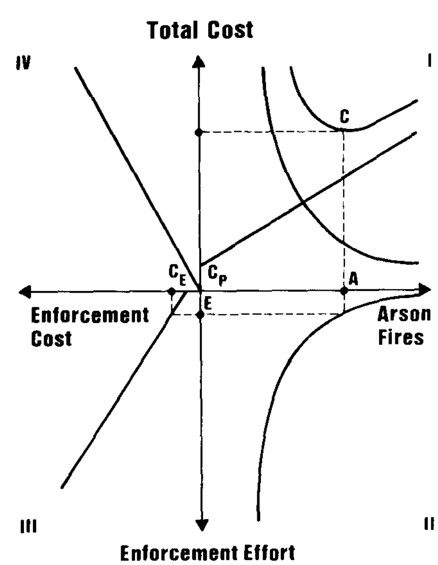

Figure 10--Four-quadrant economic model of fire prevention (Donoghue and others 1987).

mathematically calibrated fob Arkansas and for two regions within the State[6]

Individual solutions were calculated for these two regions (fig. 11). As expected, the efficient solution involves substantially more enforcement expenditures in higher value loblolly-shortleaf pine than in lower value oak-hickory areas. Sensitivity analyses of enforcement costs disclosed that substantial expenditures were justified in the loblolly-shortleaf type across a wide cost range. In contrast, increasing enforcement costs in the oak-hickory type resulted in notable reductions in the efficient level of expenditures.

We extended the model of Donoghue and others (1987) to derive a mathematical solution to the problem. (Even a simple sensitivity analysis

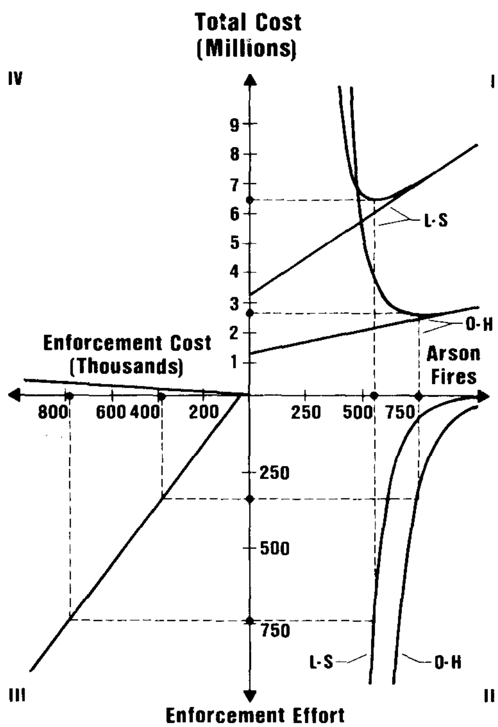

Figure 11--Optimum law enforcement levels in loblolly-shortleaf and oak-hickory forests in Arkansas (Donoghue and others 1987).

quickly becomes cumbersome with a four-quadrant model.) We started with the production function (Donoghue and Main 1985):

$$A = A_0 (E)^{-P} \quad E \geq 1 \qquad (1)$$

where: A = no. of arson fires

A_0 = no. of arson fires with no enforcement

E = units of enforcement (prosecutions + convictions + settlements)

p = productivity coefficient (-0.134)

We also used the total cost function from Quadrant I:

$$C = Cf\,(A) + Ce\,(E) + Cp \qquad (2)$$

where: C = total cost

Cf = suppression cost per fire + net value change per fire

Ce = enforcement cost per unit

Cp = presuppression cost

Equation (2) assumes that the costs per fire and per unit of enforcement are constant. Although not strictly true, conceptually we can only prevent the average fire, and economies of scale are not a major factor in enforcement. These considerably lessen the significance of this assumption and simplify the mathematics. Although we bypass the mathematical development here, it is straightforward. Substitute (1) into (2), take the first derivative of C, set it to 0 (the point of minimum total cost), and solve for E:

$$E = \left(\frac{A_o pCf}{Ce}\right)^{\left(\frac{1}{p+1}\right)} \qquad (3)$$

Note that one need not know the presuppression cost (Cp) to find the efficient solution.

[6]Eastern States values of A_o and a more detailed description of methods for calculating within-state values can be found in an unpublished report on file, North Central Experiment Station, East Lansing, Michigan.

A value of A_0 can be calculated for each State or management area to be analyzed (Donoghue and others 1987)[6]. The Eastern value of p is fixed at -0.134 (unless examining the sensitivity of a solution to the error inherent in the production function). Assuming that the average cost per fire (Cf) and cost per unit of enforcement (Ce) are known, equation (3) yields the economically efficient number of enforcement units for the management area being analyzed. Equation (1) yields the expected number of arson fires, equation (2) yields total system cost, and each part of equation (2) yields the cost of each component of the system.

By rearranging terms into two ratios (A/E and Cf/Ce), we can present the locus of all economically efficient solutions on a single two-dimensional graph (fig. 11). In the process, the number of fires without enforcement (A_0) conveniently drops out of the solution. In addition, by using the 2-standard deviation limits of the productivity coefficient, we also show the 95 percent confidence band for the result. Put another way, this region delineates the relative fuzziness of the answer (presumably computer-calculated to a precision of four decimal places).

These results provide a glimpse into the future, when economic analyses of fire prevention (and by extension, of fire management) will be the norm. Armed with a calculator and equations 1, 2, and 3 or with figure 11 and a ruler, one can generate sets of efficient solutions so that the sensitivity of the results to what is and isn't known can be determined. Such information can bolster confidence in implementation when large input changes have relatively little impact on the output. Conversely, it can quantify the benefit to be derived from more precisely measuring the value of one or more inputs.

The power embodied in this process lies in eliminating intervening calculations. Once a production function (equation 1) is defined experimentally and costs are measured, all else is mathematically derived. This permits us to go directly to the desired solution and analyze it, rather than expending considerable energy crunching numbers just to obtain a single solution. Today, the technique is only available for one fire cause and one prevention activity in one part of the country. We suspect that a modicum of research could develop a production function for engineering and railroad fires. We hope that during the next decade or two, a set of productivity curves can be developed to cover most aspects of wildland fire prevention.

Optimizing Program Mix

A key part of this activity lies in using Operations Research (OR) techniques to solve prevention problems. The past two decades are rich with OR analyses of wildland fire management problems. Martell (1982) reviewed more than 200 articles on the topic. The list of analyses is long: prevention planning, fuel management, strategic and tactical detection planning, resource acquisition and strategic deployment, resource mobilization, initial attack dispatching, extended attack management, fire impact management, and training. Martell (1982) concludes, however, that "although many of the studies. . .have produced valuable insights into complex fire problems, fire managers seldom rely on the results of OR studies to guide their decisionmaking." He lists several possible causes for this applications gap, one of which is particularly germane here--"efforts to implement OR continue to be hampered by difficulties in predicting the physical and economic consequences of alternative courses of action." In essence, OR provides powerful tools for optimizing mixes of things when their relative costs, benefits, and substitutabilities are known.

In the business of preventing wildfires, we can estimate relative costs (surprisingly crudely in most cases), we know something about the benefits for just one or two cases, and virtually nothing about substitutabilities. For example, we compared law enforcement exclusively to arson fire occurrence, yet there is a weaker (statistically marginal) relation to debris burning fires. Total law enforcement effectiveness will somehow have to be prorated between these two and possibly other causes. Similarly, rural population density explained 21 percent of the variability in debris fires and 8 percent of the variability in arson fires (Donoghue and Main 1985)--again, necessitating some form of proration. There may also be an as yet unexplored relation to other causes. At one end of the substitution scale, railroad fires and related prevention activities may be sufficiently independent of other causes that they can be treated as such. At the other end of the spectrum, measuring and distributing the effectiveness of multi-media Smokey Bear campaigns among the various fire causes would seem to be a truly challenging problem. Once we understand the technical relationships between things that we do and things that we want to accomplish, there are powerful analytical tools available to help us do more of the latter and less of the former.

TOMORROW

What does the future hold for wildland fire prevention management? Before the year 2000, we expect that daily fire occurrence prediction will be as commonplace as fire-danger rating is today. Predictions will be quantitative (e.g., number of fires, probability of large fires), and they should account for half of the observed daily fire occurrence variability in management areas on the order of a few thousand square kilometers. Within the same time frame, it should also be possible to explain two-thirds to three-quarters of the interannual variation in fire occurrence. The data are at hand, efficient computer processing techniques for large data bases are available, and we have a reasonable (though incomplete) knowledge of what's going on. What remains to be done is a decade of research in which the individual bits and pieces of what we've learned are put together in one generally applicable package.

Progress on normalizing the weather component of fire occurrence will enable us to remove much of the "noise" from prevention effectiveness data. This will, in turn, open up new opportunities to measure the effectiveness of more complex, diffused, and difficult-to-quantify prevention activities. We also expect considerable progress in normalizing other nonprevention components of fire occurrence such as sociological, economic, and demographic effects. By the year 2000, or slightly beyond, our knowledge in this field could equal our knowledge of fire-danger rating today. We emphasize that it is not necessary to understand exactly how or why a prevention activity leads to fewer fires to measure program effectiveness. This is fortunate because the historical trend of progress in understanding the how and why of wildland fire prevention leads to the conclusion that we will be well beyond even the futuring horizon of this conference before substantial progress is made in this area.

As happened for enforcement and arson fires, economic evaluation will quickly follow the measurement of prevention effectiveness. Demonstrating the feasibility of such analyses also points out the need for much better information on prevention costs and net value change than are currently available. We expect that by the year 2000, many organizations will have made considerable progress in collecting and analyzing such information, and that by the year 2010, economic analyses of prevention programs will be as common as such analyses of fire management are today.

Powerful analytical techniques for program optimization are currently available, but the interrelationships and substitutabilities between prevention activities and programs are unknown and will likely remain so for the rest of this century. Although we can solve the problem, current solutions tend to be of academic interest rather than operationally useful due, in part, to questionable inputs. As economic evaluations are completed for an increasing number of prevention programs, the usefulness of program optimization will increase. Significant progress in this final area is not likely until well into the first quarter of the next century.

Quantitative prevention management could be a reality by the year 2000. All that would be needed is a significant infusion of resources. Given the relatively low profile of prevention in current research planning, however, we see some (but not substantial) progress in the next decade or so. From a "half-full glass perspective," even some progress will make quantitative prevention management a reality by the end of the first quarter of the next century. That's about half the time that it has taken us to get this far. On the other hand, who knows? The concept might just take hold with a few innovative managers. These people might then decide to drive the system rather than letting it drive them. When that starts to happen, great things are often achieved. In our opinion, prevention management is inevitable. We can make it happen sooner or let it happen later--the choice is up to us.

REFERENCES

Bernardi, Gene C. 1970. Three fire prevention television films varying in "threat" content ... their effectiveness in changing attitudes. Res. Paper PSW)63. Berkeley, CA: Pacific Southwest Forest and Range Exp. Sta., Forest Service, U.S. Department of Agriculture; 26 p.

Bertrand, Alvin L. ; Baird, Andrew W. 1975. Incendiarism in southern forests: a decade of sociological research. Bulletin 838. Mississippi State, MS: Mississippi Agriculture and Forest Exp. Sta., Mississippi State University; 40 p.

Cunningham, A. A.; Martell, D. L. 1973. A stochastic model for the occurrence of man-caused forest fires. Canadian Journal of Forest Research 3(2): 282-287.

Dickerson, Ben E. ; Bertrand, Alvin L. 1969. Potential roles of local opinion leaders in the communication of forest fire prevention messages. Bulletin No. 639. Baton Rouge, LA: Louisiana Agricultural Exp. Sta., Louisiana State University; 20 p.

Donoghue, Linda R. 1982. Classifying wildfire causes in the USDA Forest Service: problems and alternatives. Res. Note NC-280. St. Paul, MN: North Central Forest Exp. Sta., Forest Service, U.S. Department of Agriculture; 5 p.

Donoghue, Linda R. ; Main, W. A. 1985. Some factors influencing wildfire occurrence and measurement of fire prevention effectiveness. Journal of Environmental Management 20(1): 87)96.

Donoghue, Linda R.; Simard, Albert J. ; Main, William A. 1987. Determining the economic relationship between law enforcement activities and arson wildfires: a feasibility study in Arkansas. Unpublished manuscript in review.

Doolittle, M. L. 1979. A scale for rating fire-prevention contactors. Res. Note SO-249. New Orleans, LA: Southern Forest Exp. Sta., Forest Service, U.S. Department of Agriculture; 2 p.

Doolittle, M. L.; Eller, Francis; Jackson, Robert S. 1976. Strategies for reducing incendiary fire occurrence in the south. Southeastern Area S. & P.F.-3. Athens, GA: Southeastern Area State and Private Forestry, Forest Service, U.S. Department of Agriculture; 9 p.

Doolittle, M. L. ; Kootsher, M. H.; Mercer, C. V. 1975. Relationship of personnel characteristics to fire prevention effectiveness. Res. Note SO-191. New Orleans, LA: Southern Forest Exp. Sta., Forest Service, U.S. Department of Agriculture; 3 p.

Folkman, William S. 1963. Levels and sources of forest fire prevention knowledge of California hunters. Res. Paper PSW-11. Berkeley, CA: Pacific Southwest Forest and Range Exp. Sta., Forest Service, U.S. Department of Agriculture; 22 p.

Folkman, William S. 1973. Roadside fire prevention signs ... a restudy of their effectiveness. Res. Note PSW-282. Berkeley, CA: Pacific Southwest Forest and Range Exp. Sta., Forest Service, U.S. Department of Agriculture; 6 p.

Griessman, B. Eugene; Bertrand, Alvin L. 1967. Factors related to communication of forest fire prevention messages: a study in selected rural communities. Bulletin No. 623. Baton Rouge, LA: Louisiana Agricultural Exp. Sta., Louisiana State University; 31 p.

Haines, Donald A.; Johnson, Von J.; Main, William A. 1975. Wildfire & atlas of the Northeastern and North Central States. Gen. Tech. Report NC-16. St. Paul, MN: North Central Forest Exp. Sta., Forest Service, U.S. Department of Agriculture; 25 p.

Haines, Donald A.; Main, William A.; Frost, John S.; Simard, Albert J. 1983. Fire-danger rating and wildfire occurrence in the Northeastern United States. Forest Science 29(4): 679-696.

Haines, Donald A.; Main, William A.; McNamara, Eugene F. 1978. Forest fires in Pennsylvania. Res. Paper NC-158. St. Paul, MN: North Central Forest Exp. Sta., Forest Service, U.S. Department of Agriculture; 20 p.

Heineke, J. M.; Weissenberger, Stein. 1974. An analysis of wildfire prevention. IEEE Transactions on Systems, Man, and Cybernetics SMC-4(6): 513-522.

Kerr, Ed. 1958. Southerners who set the woods on fire. Harper's Magazine 217 (1298): 28-33.

Kourtz, Peter. 1984. Decision)making for centralized forest fire management. Forestry Chronicle 60(6): 320-327.

Lynham, T. J.; Martell, D. L. 1985. An analysis of annual people-caused forest fire occurrence in Ontario. In: Proceedings of the Eighth Conference on Fire and Forest Meteorology; 1985 April 29-May 2; Detroit, MI. Bethesda, MD: Soc. of American Foresters; 200-207.

Martell, D. L. 1982. A review of operational research studies in forest fire management. Canadian Journal of Forest Research 12(2): 119-140

Meyer, Earl. 1986. Evaluating arson-caused forest fires in Wisconsin, 1982-85. Fire Management Notes 47(3): 22-25.

Nickey, Bradley B. 1980. Fire occurrence analysis by c control charts. Unpublished draft supplied by author.

Nickey, Bradley B.; Chapman, Clifford B. 1979. Evaluating fire prevention effectiveness

through a probability model. Fire Technology 15(4): 291-306,.
Pottharst, Ed; Mar, Brian W. 1981. Wildfire prevention engineering systems. Canadian Journal of Forest Research 11(2): 324-333.
Shea, John P. 1940. Getting at the roots of man-caused forest fires: a case study of a southern forest area. General Report. Forest Service, U.S. Department of Agriculture; 78 p.
Siegelman, Ellen Y.; Folkman, William S. 1971. Youthful fire-setters ... an exploratory study in personality and background. Res. Note PSW-230. Berkeley, CA: Pacific Southwest Forest and Range Exp. Sta., Forest Service, U.S. Department of Agriculture; 6 p.
Simard, A. 1975. Wildland fire occurrence in Canada. Map. Ottawa, Ontario: Canadian Forestry Service, Environment Canada.
Simard, A. J. 1976. Wildland fire management: the economics of policy alternatives. Forestry Tech. Report 15. Ottawa, Ontario: Forest Fire Research Institute, Canadian Forestry Service, Environment Canada; 52 p.
Simard, A. J.; Eenigenburg, J. E.; Hobrla, S. L. 1987a. Predicting extreme fire potential. In: Proceedings of the Ninth Conference on Fire and Forest Meteorology; 1987 April 21-24; San Diego, CA. Boston, MA: American Meterological Society (in press).
Simard, A. J.; Graham, J. D.; Young, G. A.; Redmond, R. D. 1979. Canadian forest fire statistics: 1961)1966. Information Report FF-X-70. Ottawa, Ontario: Forest Fire Research Institute, Canadian Forestry Service, Environment Canada; 42 p.
Simard, A. J.; Haines, D. A.; Main, William A.; 1987b. Global teleconnections and wildland fire activity in the United States. Unpublished manuscript in review.
Ward, P. C. 1985. Structure and function of four computer programs for decision support. AFMC Pub. No. 201. Sault Ste. Marie, Ontario: Ontario Ministry of Natural Resources, Canada; 61 p.
Wetherill, G. Richard. 1982. Forest fire prevention programs and their evaluation. Res. Note SO)282. New Orleans, LA: Southern Forest Exp. Sta., Forest Service, U.S. Department of Agriculture; 5 p.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

An International Perspective of Wildland Fire 2000[1]

R. L. Bjornsen[2]

Abstract: A steadily shrinking forest land base and the social demands of an expanding population will require utmost skill from land managers, if forest products are to meet the demands of 6 billion people in the year 2000. Developed nations have recognized fire's role, both as a tool and a destructive force. By contrast, developing nations have not instituted adequate policy in coping with wildland fire. There is need for government support of programs that will maximize the beneficial use of fire in the forest, while recognizing its destructive force and taking adequate protection measures. The consequences of inadequate wildland fire management must be made known; options for cost/benefit management developed; and technology transfer subsidized by aid programs to developing nations. Wildland fire in the year 2000 must incorporate strategies that will be compatible with social forestry programs.

WHAT IS HAPPENING NOW?

There is a wide disparity of policy in the role of wildland fire among nations worldwide. Programs range from the most sophisticated use of electronic equipment to virtually no measures of fire regulation and use.

Developed Nations

For the most part developed nations that have wildland fire occurrence have established fire protection goals to cope with catastrophic fires that endanger lives and property. Beginning in the 1960's, a few countries such as Australia, Canada, and the United States, saw the need to adopt goals which fostered the use of prescribed fire, or fuel modification, to reduce fuel accumulations and thereby prevent large wildfires.

In North America, where lightning is prevalent. Canadian and U.S. policy has included provision for the natural role of fire in the ecosystem. Here fires started by lightning are allowed to burn unrestricted within carefully prescribed conditions. While these prescriptions are largely confined to wilderness and roadless mountain areas, public land managing agencies are, for economic reasons, developing prescriptions for free burning fires regardless of ignition source.

Prescribed fire has long been used as a silvicultural tool in developed countries. In recent years goals have been set to provide for fire use to enhance wildlife habitat, watershed, livestock forage, vegetative type conversion, and scenic values. But in the main, fire is still viewed as a destructive force to be surpressed quickly with minimum damage to the resource.

Now, a new threat has arisen in the more affluent countries where the encroachment of urban habitation into wildland areas has caused increased threat of fires spreading from wildlands to intermingled structures or vice versa. This has been termed the "urban/wildland interface fire problem," and it is adding a whole new dimension to wildland fire protection policy. (National Fire Protection Association 1986)

[1]Presented at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe. California.

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Developing Nations

By contrast, developing nations--with a few exceptions--have either ignored policy dealing with wildland fire or have ineffectual protection programs.

At the forefront is a conflict between the need for social improvement of the rural class standard of living versus achieving wildland fire management goals. On the one hand there can be a policy that promotes colonization of wildlands and attendant clash and burn agricultural practices. On the other hand, exists a serious lack of a policy to deal with man-caused fire.

Often there is complacence that a short "dry" season in tropical countries poses no threat to unwanted fire. This belief should have been dispelled by the severe fires in Indonesia and the Philippines during the 1983 dry season, when millions of hectares of forest and grassland were lost to fire.

For the most part in developing countries the primary concern of foresters is to regulate forest production through harvest and silvicultural practice. They have little training or concern for the role of fire in wildlands, except to suppress it if it is a problem. Prescribed fire as a tool in wildland management is virtually non-existent.

Forestry assistance programs sponsored by Food and Agricultural Organization (FAO), United Nations, and bilateral aid programs from developed countries, provide minimal funding or technical expertise in fire management. An exception to this can be found in a Canadian assistance project in China, and a FAO project in India. Both projects are substantive, but are aimed primarily at presuppression and suppression programs.

WHERE ARE WE HEADING?

Advanced technology is being shared between developed countries. Australia, Canada, and the United States are the free world leaders in these areas: computer application to fuel inventory, lightning prediction, presuppression planning and tactical/strategic suppression decision making; basic/applied research on fuels, fire meteorology, and behavior: and equipment development.

Other developed countries are adopting selected programs and research results to fit their needs mostly for suppression operations. Funding is of course a limiting factor, becoming available only following the classic response of governments to disastrous wildfire threat to life and property rather than by recognition of a calculated requirement.

The "high tech" explosion in electronics and its ripple effect throughout research and development have challenged the leading nations to incorporate new innovations in their fire management programs.

By contrast, when these same nations provide expertise to developing countries they often try to foist off this "Cadillac" technology when their clients have hardly advanced to the "VW Bug" stage. The result is often a fancy report relegated to the dead file, or worse yet, sophisticated equipment lying unused and rusting for lack of maintenance.

On the one hand we are heading towards sophisticated, computer driven fire management programs that will enable managers to use tire more effectively as a resource tool and yet curb its excesses when it escapes control. On the other hand developing countries are caught between social needs of burgeoning populations, a dwindling forest resource, and low recognition of wildland fire's role in the ecosystem.

WHAT DO WE WANT TO HAPPEN?

The three leading nations mentioned above, have recognized wildland fire potential, both good and bad. For the most part the politicians are educated in the need for funding presuppression programs, and they recognize the value of research and development in fuel management and prescriptive use of fire--even if they do not provide adequate funding.

Resource agencies should continue pursuit of a strong R&D program, incorporating research results into operational use. Planning must yield efficiencies that will gain political support for both fire use and protection funding. Prevention must assume priority recognition and support. The urban-wildland interface problem will become more acute and must be dealt with if loss of life and property is to be minimized.

Bilateral assistance to other developed countries should continue. Rather than force feed new technology into their programs, transfer of advanced systems should be geared to what can be assimilated by the current level of expertise in fire management in those countries. In other words, "one doesn't get to heaven in one jump."

Developing countries are another matter, where fire managers move much more slowly. Improvement in fire management programs has to consider the socioeconomic status of each country in question. The goal would be to introduce technology suited to the culture, and which treats basic requirements first. The challenge will be not to move too fast even though great need is apparent.

In many cases education of land managers to the role or threat of fire would be the main thrust, rather than focusing on more tangible results in their programs. In fact education of the assisting experts in a developing country's culture, should be a prerequisite to working with their problems.

In total we need to develop and expand new technology, apply existing technology to operational use, and introduce these systems into world utilization at a pace that countries can accept.

HOW DO WE WANT IT TO HAPPEN?

Fire managers need to weigh the consequences of wildfire damage against the present and planned level of protection. Political leaders should be provided an array of options from which to fund a presuppression program. A preferred option should be recommended.

In each case the role of fire as a management tool needs to be identified. Prescribed use of fire to achieve protection goals, silvicultural treatment, watershed enhancement, wildlife habitat improvement, and food production should be quantified.

Applied research should be emphasized, particularly in less developed countries. The goal would be to obtain quicker results on the effects of fire and its use. Basic research must continue apace to exploit electronic advances. Equipment development and testing should be fostered to effect transfer of new hardware to field operations.

Wildland fire's role in social forestry programs must be delineated. The conflict between social programs that promote colonization of forested land with its slash/burn agriculture must be mitigated. Indiscriminate burning of forest and grassland must be stopped and replaced, where required. with fire by prescription.

The occurrence of large, damaging fires in tropical forests should be studied. Climatic conditions, such as El Nino need to be identified and fire danger systems developed to assist tropical countries to prepare for wildfires during their dry seasons.

The term "technology transfer" is almost a cliche. Nevertheless the sharing of knowledge is vital to achieving goals in any endeavor; fire management is no exception. If developing countries are to advance to even a basic protection status, much less a prescriptive fire use program, they will need assistance from developed nations.

The sticking point is funding these aid programs. Education appears to be the key. With some exceptions, most forestry programs give priority to managing fire only as it poses a threat to meeting harvest goals. Sometimes fire is not even perceived as a threat because of low occurrence. Yet poorly planned and protected plantations can be in found most countries, including developed ones.

Why education? Because it will create an awareness of fire's role in resource management and of the need for the inclusion of fire managers on planning and operational teams. It will expand forestry training to include more fire subjects in the core curricula.

Education will offset the tendency to "jump to the king row". Invariably, I find forestry officials have read or heard about high tech equipment, typically aerial delivery systems. and want to purchase a helicopter bucket; a sophisticated pumper; contract for an air tanker, without knowledge of how to effectively employ or maintain the equipment.

In one developing, temperate zone country for example, the forestry department was persuaded by its aviation group to purchase helicopter buckets for large fire operations. They had neither an effective initial attack organization, adequate ground/air communications, much less a trained, large fire cadre who knew aerial delivery tactics.

INTERNATIONAL WILDLAND FIRE MANAGEMENT IN YEAR 2000

Developed Nations

The leading nations are moving rapidly into full acceptance of fire's existing and potential roles in the ecosystem. Their capability to reduce damage from large conflagrations will increase as computer assisted programs, improved fire behavior forecasting, advanced logistical support, new airborne electronic intelligence systems, and new suppressants come on line.

Use of prescribed fire to reduce natural fuel accumulations will expand. Mosaic patterns of fuel treatment areas will inhibit the spread of wildfire in fire prone fuels. Burn prescriptions will become more accurate as research in fire effects/behavior and better weather forecasting come on line.

The more affluent countries will experience greatly increased urban sprawl into wildland fuels. Gradually, standards for fire resistant structural materials and preventive measures around buildings will be enforced, but not without bitter fighting from special interest groups. Wildland fires involving structures will escalate until severe loss of life and property become intolerable, causing governments to set standards and enforce prevention measures.

There will be greater cooperation between all countries to cope with wildfire disasters. Special teams to provide logistical support and operational control assistance will become commonplace, as now occurs between Canada and the United States. Less developed countries will improve basic protection programs, although there will still be the "king row" syndrome to contend with.

More onsite training will take place using bilingual experts. Training syllabi will be translated into more languages than exist today.

Developing Nations

The world population is estimated to increase by 1 billion by 1999. Most of this increase will occur in developing countries which can ill afford to feed, heat, and clothe their people now, much less the forecasted increase.

The present demand of fuelwood for cooking and heating is exceeding timber growth rates in most countries. Fast-growing species are being introduced, but at best only modest success can be claimed. Typically the wood is harvested before optimum growth has been obtained.

Old growth forests will largely be cutover by 2000. Slash and burn agriculture will continue unabated as governments attempt to provide living space for rural people, or trespass occupancy is ignored. Agro (social) forestry will not grow significantly unless governments can underwrite startup costs and maintain the projects until they begin to pay off. Unfortunately these programs are too long term to compete with other social needs.

Although, today, forests may not be perceived by politicians as a renewable resource which is of vital need, this will change as the acute demand for fuelwood and structural forest products increases.

The cost of fossil fuel will become prohibitive and there will be an awakening to the diminishing supply of wood fiber.

Fire managers have a role in this complex cycle. They are an integral part of the planning and execution process of wildland management. The challenge is to educate and improve tools and skills, to be ready for the undeniable role we must fill.

REFERENCE

National Fire Protection Association. 1986. Wildfire Strikes Homes. The report of the National Wildland/Urban Fire Protection Conference. Laughlin, Jerry; Page. Cynthia. eds. NFPA SSP-86. Quincy, MA; 89 p.

Poster Papers

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Evaluation of National Fire Management System's Escaped Fire Situation Analysis[1]

A. P. Dimitrakopoulos[2]

According to National Fire Management Analysis System (NFMAS) assumptions, escaped fires are those that exceed the defined maximum size (1000 acres), containment time limit (8 hours), or the capabilities of the suppression forces dispatched by the user. Acreage for each fire identified as an escape is automatically assigned within the initial attack module from a user-established "escaped fire table" based on the annual frequency of each escaped event calculated by the program (USDA Forest Service 1983). The purpose of this table is to provide a consistent approximation of expected escaped fire size distributions for analysis purposes. It is based on the assumption that, for a given area, the historical size and annual frequency of escaped fires can be used reasonably to represent the average fire size over time for escaped fire events of a similar annual frequency in the analysis. Data from a 20-year period must be used as the basis for developing the "escaped fire table," to provide a sufficient distribution of historical fires to represent the probability of future escaped fires for the analysis. The escaped fires that occurred in the forest during the 20-year period are tabulated and grouped into fire size classes. Professional judgment is required to establish the fire size classes and determine whether a particular size class is appropriate for a given fire management analysis zone smooth distribution of average fire size classes and their related annual frequencies. The annual frequency of each fire size class is calculated by dividing the number of escaped fires that are grouped in each size class by the number of years that were used in the analysis.

NFMAS procedures for estimating the final fire size of escaped fires rely heavily on the program user, because the user alone determines how many escape fire events will be included in each fire size class. The average size that will be assigned to each fire size class represents the arithmetic mean of the escaped fire sizes that are included in this size class, and consequently, depends on the number of fires that were grouped in this class according to the user's judgement. Care must be taken in assigning an average size at each escaped fire size class to ensure that the size predicted is consistent with the expected annual frequency of the event as evidenced by the historical records. In addition, the annual frequency that will be assigned to an average escaped fire size class depends upon the number of escaped fire events that are included in this size class. Thus, based on the historical annual frequencies of the escaped fire size classes and the annual frequency that was calculated by the program for a certain escaped fire event, a final fire size is assigned to the escaped fire.

DISADVANTAGES OF USING NFMAS PROCEDURES FOR LARGE FIRES

The NFMAS procedures for assigning acreage to fires that escape the initial attack capabilities and become large, have several disadvantages:

[1]Presented at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

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1. Large fires are stochastic--not periodic--events with changing occurrence probabilities over time. Therefore, their annual frequencies and sizes can not be predicted from their historical distribution.

2. NFMAS escaped fire size procedures rely heavily on the user. The user decides the number of of classes of average escaped fire sizes and the number of fire events in each size class that will be used to create the escape fire table. In this way, as explained above, the user determines the average size and the annual frequency that will be assigned to each escaped fire size class in the escaped fire table. Arbitrary decisions regarding the number of escaped fire size classes may lead to assigning annual frequencies to size classes that do not reflect the actual fire history of the area. Since the user is free to select as many size classes as are thought appropriate and no specific instructions are given in the NFMAS documentation, different users may come up with different sizes and annual occurrence frequencies of escaped fire events for the same forest, after conducting the initial attack analysis (IAA) fire behavior simulation. This will result in different suppression expenditures and fire losses for the same fire management zone, creating, confusion and uncertainty in decision making.

3. When the number of escaped fires that occurred in the forest over the 20-year period is small with a wide distribution of sizes, then the calculated annual occurrence frequencies of the escaped events are not realistic and reliable.

4. Drastic changes in fuels, fire suppression potential and practices, or fire management objectives in an area may change the fire environment to such an extent that the use of historical data for the prediction of large fire sizes and frequencies in the future, may be meaningless.

Therefore, a modification of the NFMAS procedures for estimating the action of escaped fires is necessary in order to eliminate subjective judgments in the creation of the "escaped fire table," and to avoid nonrepresentative fire sizes and occurrence frequencies in a certain fire management analysis zone.

PROPOSED MODIFICATION OF NFMAS PROCEDURES FOR LARGE FIRES

Assigning large fire sizes according to their expected annual frequencies by intensity level will be a more consistent and realistic procedure for assigning a final size to escaped fires. The higher the fireline intensity of a fire, the higher the probability will be that the fire will escape and become large. As the fireline intensity increases, the rate of increase in fire size increases too, since the combustion rate and the rate of fire spread will be higher and, therefore, the suppression efforts more difficult.

For the fire behavior simulation procedure used in NFMAS to reflect reality, it is logical to expect most of the simulated escaped fire events to occur in the last three IAA fire intensity levels (4, 5, and 6). since they represent the most likely conditions that can result in an escaped fire.

Procedure

A procedure for assigning a final escaped fire size to fire intensity levels 4, 5, and 6 is given below:

The sizes of escaped fires that occurred in the fire management analysis zone over a time period (not necessarily 20 years) are put in ascending order. The total number of escapes is divided by three, including the same number of escaped events in each of the three fire size classes that resulted from the division. Dividing the total number of escaped fires by three, determines the number of the escaped fire size classes that will be used in the escaped fire table, avoiding in this way any arbitrary selection and providing consistent methods regarding the number of escaped fire size classes that will be used in the analysis.

Next, an average fire size is calculated for each size class by dividing the total number of acres burned in each size class by the number of fires that are grouped in this class. If, after grouping the fires in to three categories, the sizes of the fires in each are not more or less uniform, then extreme values can be excluded. Although this exclusion may be subjective, it ensures a smooth distribution of average fire sizes in the escaped size classes.

Finally, the escaped fire table is created by assigning the calculated average fire sizes to the last three fire intensity levels. Since the escaped fire sizes were grouped in ascending order the largest average fire size will be assigned to intensity level 6, while the smallest will be assigned to intensity level 4. Thus, a final size will be assigned to each escaped fire event according to the fire intensity level in which the fire occurred and not according to its calculated annual frequency.

Advantages

The proposed modification of the NFMAS procedures for escaped fire size has the following advantages:

1. The proposed modification is based on the fact that large fires demonstrate high fireline intensities. Since fireline intensity determines the suppression difficulties that are to be expected, higher intensities result in larger fire sizes. With the proposed procedure, large fires will be assigned to high fireline intensities, a concept which reflects reality.

2. In my modification, the escaped fires are not assigned according to their expected annual frequencies. The reason is that large fires are stochastic and not periodic events, have unpredictable occurrence probabilities and, therefore, their frequency cannot be predicted based on their historical occurrence.

3. The user's involvement in selecting the number of average fire size classes and, thus, in selecting the average fire size that will be assigned to each class, will be eliminated. Arbitrary classifications, which could lead to unrealistic annual frequencies for certain fire size classes in the escaped fire table will be avoided. Thus, unrealistic results due to escaped fire annual frequencies that are not representative of the fire sizes assigned to them on the escaped fire table, will not occur.

4. The annual fire frequencies are intermediate calculations in the NFMAS fire behavior simulation after the program run has been completed. These calculations create difficulties in the program calibration since the user does not know in advance the acreage that will be assigned to the escaped fires that occur at a certain fire intensity level. This may lead to unexpected results, since the user has absolutely no control on the acreages that will be assigned to an escape event from the escaped fire table. With the proposed modification the user will know from the beginning the fire size that will be assigned to an escaped fire at a certain intensity level and therefore will be able to better calibrate the model. Thus, additional program runs, time and money will be saved since it will not be necessary to modify the escaped fire table and rerun the program every time that unrealistic fire sizes occur.

5. Fires will not escape at low intensity levels (1, 2, 3) where fireline construction is adequate to hold the fire and handcrews are effective. Lower program levels, due to reduced suppression expenditures, will not result in escaped fires which occur in unrealistically low intensity levels.

6. The acres burned annually will depend on the number of escaped fire events and not on the calculated annual frequency of each escaped fire.

The proposed modification of NFMAS procedures for assigning a final size to escaped fires will improve the model's inherent accuracy for the reasons mentioned.

REFERENCE

U.S. Department of Agriculture, Forest Service. 1983. Fire Management Analysis and Planning Handbook 5109.19

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range
Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Concepts for Future Large Fire Modeling[1]

A. P. Dimitrakopoulos and R. E. Martin[2]

Abstract: A small number of fires escape initial attack suppression efforts and become large, but their effects are significant and disproportionate. In 1983, of 200,000 wildland fires in the United States, only 4,000 exceeded 100 acres. However, these escaped fires accounted for roughly 95 percent of wildfire-related costs and damages (Pyne, 1984). Thus, future research efforts logically will focus on the difficult and complicated task of modeling large fires.

Large fires often demonstrate higher fireline intensities, different modes of propagation and different distribution patterns through time than do steady-state fires. It is essential, although difficult, to simulate, model, and predict large fire management considerations. In the future, wildland fire modeling efforts are likely to focus on the concepts and peculiarities that large fires present in terms of behavior, suppression and control attributes. This paper reviews the problems that large fires pose to fire analysts.

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CONSIDERATIONS FOR MODELING LARGE FIRES

No known computer model is currently available that can reliably simulate the behavior of large fires. The reasons are several:

1. Heterogeneous conditions of weather, fuel, and topography are encountered during a large fire because of the lengthy burning times and the large size that the fire finally attains. Hence, every model's inherent assumptions of fuel and weather continuity and uniformity are violated by large fires.

2. Large fires spread by means other than a flaming front through surface fuels. Crowning and spotting are different modes of propagation that often occur during a conflagration.

3. Fire-related phenomena--such as firewhirls, horizontal roll vortices, and convection columns--not common during small fires, often are present during large fires. Those phenomena magnify the spread and heat output rates and make the suppression efforts more difficult.

4. Large fires often demonstrate sudden, exponential increases in fireline intensity ("blow-up" phenomenon) accompanied by violent convection, which is sufficient to preclude direct control or to upset existing suppression plans. Fires seem most likely to blow up when high loads of heavy and dry fuels, unstable atmosphere, and windspeeds greater than 20 miles per hour exist simultaneously (Byram, 1959).

5. Large fires burning over extended periods of time, under the influence of wind and topography, assume irregular shapes that do not follow the typical elliptical fire shape that most models assume.

6. Large fire suppression includes various methods of fire control, other than fire containment through fireline construction. Common containment models, used in fire simulation, cannot realistically represent complicated fire suppression tactics.

7. It is difficult to plan a potential large fire suppression organization since the use of shared resources makes the availability of firefighting forces unpredictable.

8. Fire suppression strategies differ among fire control officials, and they are almost impossible to generalize and to model.

9. Large fires are stochastic events with changing occurrence probabilities over time, and therefore, historical data for large fire distributions would give a wide variation in predicted fire sizes and behaviors.

Traditional fire simulation approaches and fire gaming procedures are the two methods applied to large fire modeling in the past.

Mathematical Simulation

Traditional mathematical fire simulation procedures are used in National Fire Management Analysis System (NFMAS). NFMAS assumes that fires over the escape threshold grow to sizes consistent with historical large fire distributions. Also, fires that exceed the defined maximum size (1,000 acres), or time limit (8 hours), or the capabilities of the suppression forces supplied by the user, are identified as escaped.

Acreage for each fire identified as an escape by the initial attack module is automatically assigned within the program from a user-established "escaped fire table" based on the program-calculated annual frequency of each escape event. The size is based on the assumption that, for a given area, the historical escaped fire size/annual frequency relationship can be used reasonably to represent the average fire size for escaped fire events of a similar frequency in the analysis. Professional judgement is required to establish the fire size classes and to determine whether a particular size class is appropriate for a given fire management zone.

The NFMAS procedures for escaped fires have two disadvantages: (1) They rely heavily on the user. The user decides the number of escaped fire size classes and the expected annual frequency of each size class, and (2) Large fires are stochastic and not periodic events and therefore their annual frequencies cannot be predicted from their historical distribution.

Rothermel's (1972) mathematical model predicts the rate of spread, reaction intensity and flame length of surface fires burning in a steady-state condition, in a homogeneous, continuous fuel bed contiguous to the ground. Fire suppression models measure suppression effectiveness as a fireline construction rate. When the total fireline construction rate exceeds the fire's rate of perimeter increase, and the time limits are not exceeded, the fire is considered contained. In the initial attack analysis (IAA) program, the probability of violating this assumption increases with the size of the fire.

Fire Gaming

On the other hand, fire gaming procedures depend on consultation with fire experts to simulate fire suppression effectiveness and fire behavior. Schultz (1966) used the fire gaming technique to study the decisionmaking processes of fire bosses. Fire gaming has the advantage over the use of historical data in that it may be possible to categorize an expert's opinion and decision criteria, thus gaining insight into the problem being analyzed. However, fire games are essentially nothing more than educated guesses in which it is difficult to separate true understanding from personal bias. Additionally, it has been almost impossible to convert expert opinions to computer programming, although Fire Economic Evaluation System (FEES) and Fire Operational Characteristics Using Simulation (FOCUS) are two programs that use the gaming process in order to deal with large fire outcomes based on statistical fire size data (Mills and Bratten 1982).

Certain questions regarding expected fire behavior and possible suppression methods require fast and correct answers for successful and cost-efficient large fire control: How fast will the fire spread? By what means? What will be its final size? Also, how will we attack the fire? At what cost? What is the best combination of fire suppression techniques? By what criteria will we decide on the best of alternative solutions in an escaped fire situation analysis?

Depending on their behavior characteristics, fires can be classified into conflagrations and mass fires (Pyne 1984). Both categories demonstrate high energy output rates resulting from high spread rates in the case of conflagrations and from large areas of combustion in the case of mass fires. Mass fires remain stationary with well formed convection columns, while conflagrations move fast, forming a well defined front. During a large fire, the means of propagation change dramatically. Spotting, crowning, firewhirls and blow-up are phenomena that have to be modeled and incorporated in large-fire simulation models. To do this, more fundamental work in the field of fire physics is needed to understand, explain, and adequately simulate these extreme fire behavior phenomena.

The use of stochastic procedures that would yield probabilistic estimates of large fire frequency and size versus the point estimates of deterministic mathematical models appears to be one realistic means for large fire prediction. Large fires are not periodic events and, therefore, their distribution patterns through time cannot be predicted from existing fire data. Fire history and statistical analysis, although more simple to analyze and model, do not seem to be useful in predicting large fire frequency.

The least-cost-plus-loss theory in fire economics is not sufficient for large fires since there is lack of correlation between presuppression expenditures and area burned when the fire load exceeds the maximum capabilities for which the fire suppression organization was designed (Mills and Bratten 1982).

The selection of proper decision criteria is often a serious problem that arises during analysis of an escaped fire situation. Cost-efficiency cannot always be the most important criterion for the selection of the best alternative in all cases. On the other hand, a consistent decision procedure is needed for the selection of the appropriate large fire suppression alternative.

The incorporation of the escaped fire situation analysis in the computerized programs of a fire management system and the use of linear programming for the best allocation of suppression forces seem to be appropriate. Computerized models will be able to conduct the escaped fire situation analysis fast and effectively, coming up with the best alternative based on multiple decisionmaking criteria.

RECOMMENDATIONS

The following suggestions are offered for large-fire modeling efforts:

1. The use of stochastic simulation models seems to be the most appropriate for large fire modeling. Stochastic models are preferred because they give probabilistic estimates of large fire frequency and size versus the point estimates that a deterministic model would yield. This suggestion is based on the fact that large fires are not periodic events and seem to follow a frequency-intensity distribution rather than a time distribution. Also, since the physics and interactions of extreme fire behavior are very complicated, and presently unknown, a simulation model would be more preferable over a mathematical model based on the fundamental laws of physics. Since large fire behavior is erratic and difficult to measure, the creation of an empirical model does not seem feasible. On the other hand, a simulation model, which attempt to simulates the real world situation, even though simplistically, makes the analysis relatively understandable.

2. More research in the field of fire physics is necessary to understand and explain the means of fire propagation during extreme fire behavior. Dimensional analysis offers one powerful means of predicting extreme fire behavior. In such situations, where we know many of the physical variables involved but not the mathematical relations among them, combining several variables into a few dimensionless groups will enable us to model fire behavior under a wide range of conditions.

3. Fire effects models are necessary for the appraisal and prediction of fire-related damages. Fast and effective decisionmaking during escaped fires will be possible with the computerization of the procedures of an escaped fire situation analysis.

4. The application of linear programming for the optimal use and allocation of suppression forces should be considered.

5. A revision of the present fire economics least-cost-plus-loss theory would be helpful for money allocation during presuppression fire planning, and other means must be available for analysis of large fires.

CONCLUSIONS

Fire management decisions will increasingly rely on computerized fire simulation models. Thus, large-fire modeling is an area of fire science that requires special and increased attention.

REFERENCES

Byram, G. M. 1959. "Combustion of forest fuels" and "Forest fire behavior." In: Forest Fire: Control and Use. Davis, Kenneth P., ed., chapters 3 and 4.

Mills, Thomas J.; Bratten, Frederick W. 1982. FEES: Design of a Fire Economics Evaluation System. Gen. Tech. Rep. PSW-65. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture.

Pyne, Stephen J. 1984. Introduction to wildland fire. New York: John Wiley and Sons, Inc.; 455 p.

Rothermel, R. C. 1972. A mathematical model for predicting fire spread in wildland fuels. Res. Paper INT-115. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service. U.S. Department of Agriculture.

Schultz, R. P. 1966. Game simulation and wildland fire. Journal of Forestry 64(12):791-800.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

CFES--The California Fire Economics Simulator: A Computerized System for Wildland Fire Protection Planning[1]

Jeremy S. Fried, J. Keith Gilless and Robert E. Martin[2]

Abstract: The University of California's Department of Forestry and Resource Management, under contract with the California Department of Forestry and Fire Protection, has developed and released the first version of the California Fire Economics Simulator (CFES). The current release is adapted from the Initial Action Assessment component of the USFS's National Fire Management Analysis System and features a greatly enhanced user interface. Research priorities include exploring alternatives to per acre net value change to better account for localized values at risk, addressing the issue of determining final sizes of escaped fires and developing enhancements to the Initial Attack Module to improve its realism.

The University of California, Berkeley, in cooperation with the California Department of Forestry and Fire Protection (CDF), is developing the California Fire Economics Simulator (CFES), it is a package of computer programs designed to evaluate the CDF's wildland fire protection organization and alternative protection strategies. The first component of this simulator, the Initial Attack Module (CFES-IAM version 1.11), has been released and is outlined in this paper. Some improvements envisioned for the next version of CFES-IAM and an outline of proposed large fire and economics modules are also presented.

THE PROBLEM

With the annual cost of wildland fire control in California exceeding $200 million, those with fiduciary responsibility have sought to introduce systematic economic criteria into the CDF budget allocation process. In 1985, the Board of Forestry formally charged the CDF with conducting a rational analysis of the CDF's fire protection program and reporting preliminary results in August 1987. Initially, the CDF considered the possibility of adopting the Forest Service's Initial Action Assessment (IAA) model of the Forest Service. U.S. Department of Agriculture, as the vehicle for this analysis; however, a pilot program revealed several problems with IAA's assumptions and operational characteristics.

One problem intrinsic to IAA's design is its heavy reliance on the cost plus net value change (C+NVC) statistic for comparing fire protection alternatives. Although the C+NVC criterion is an established concept in fire economics, and may be entirely appropriate for a land management agency like the Forest Service its applicability is questionable for wildland and urban-wildland intermix zones characterized by private ownership and public fire protection. Reliance on the C+NVC criterion to determine the "optimal" level of protection fails to address the important equity questions inherent in a situation where costs are borne publicly and losses privately (and by only a portion of the tax-paying public).

[1]Presented at the Symposium on Wildland Fire 2000, April 27-30. 1987. South Lake Tahoe, California.

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Reliance on per acre net value change calculated over extensive areas with similar fuels seems inappropriate for California, given its extremely heterogeneous wildlands where localized habitation developments dominate net value change calculations. Net value change on Forest Service lands is usually dominated by timber losses which may, in fact, be spread homogeneously over the analysis area. However, the concept of an expected per acre NVC becomes less meaningful in the context of California's problem.

Another problem with C+NVC calculations in IAA is the reliance on an exogenous determination of the final size of escaped fires. When the acreage attributed to these non-modeled "escaped" fires drives the C+NVC criterion, the assertion that IAA "models" or "simulates" fire protection "economics" becomes somewhat questionable.

CDF recognized the potential of an enhanced IAA-style analysis, but was cognizant of the program's limitations for their specific needs. Consequently, CDF contracted with the Department of Forestry and Resource Management at the University of California, Berkeley, to develop an alternative computerized system for wildland fire protection planning--the California Fire Economics Simulator (CFES)--with the assistance of the CDF planning staff.

Because of the magnitude of the CDF fire protection organization and the extensive data requirements and local expertise that would be needed for a realistic evaluation of it, it was immediately obvious that a workable system would need to operate in a distributed fashion, with analyses conducted at the ranger unit level, and contain provisions for aggregating results statewide. It was also apparent that the system would have to account for the random nature and special considerations of structure losses, and incorporate more realistic assumptions about fire behavior and protection strategies than those contained in IAA. Finally, an overriding consideration was ease of use by field personnel with varying degrees of computer experience. Because CDF cannot afford the luxury of hiring expert analysts to run this model, but does have a distributed network of MS-DOS compatible computers installed at all ranger unit command centers, creating an interactive, micro-computer based enhancement of the IAA program appeared to be the best choice.

CURRENT STATUS

After carefully examining of the IAA FORTRAN code provided by the Forest Service, the authors decided to rewrite the physical simulation component of IAA in Turbo Pascal[3] to facilitate future enhancements and to permit development of a more sophisticated, interactive user interface.

The first component of the CFES system, CFES-IAM version 1.11, has been released. Since the simulation mechanics of this version and IAA are essentially the same, some IAA analysts may find CFES-IAM to be an attractive alternative to IAA. Several enhancements have been identified and proposed for future releases of CFES-IAM. In addition, large fire and economic evaluation modules of CFES will be developed in the coming months.

OPERATION AND CONTENT OF CFES-IAM VERSION 1.11

CFES, will eventually consist of three modules: initial attack, large fire, and economic evaluation. CFES-IAM, the first module, facilitates the comparison of alternative initial attack dispatching and deployment systems with respect to expected annual frequencies of escaped and contained fires, total area burned by contained fires and the distribution of this area by fire size and dispatch level, and firefighting costs for contained fires. While the simulation component of the first version of CFES-IAM is essentially identical to that of the Forest Service's IAA, CFES-IAM features a more sophisticated user interface, truly interactive operation, more detailed reporting on "escaped" fires, more flexible reporting of simulation results and enhancements to the treatment of air attack and helicopter water drops.

CFES-IAM program operation consists of three phases: a data entry/editing phase, a simulation phase, and an output presentation phase. For an initial analysis, the user enters information describing a fire management analysis zone (FMAZ) and representative fire locations within that FMAZ, fire history,

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[3]Borland International, Turbo Pascal version 3.0 Reference Manual, 1985, available from Borland International Inc., 4585 Scotts Valley Drive, Scotts Valley, CA 95066.

simulation limits, size class limits for reporting simulation outcomes and costs, and fireline production rates, response times and dispatch criteria for up to 50 firefighting resources. Data entry is accomplished via error-trapped, interactive screens, and data can be saved to disk files for later simulations. Once a data set has been entered or loaded from disk, it can be modified as needed using these same interactive screens. Pressing a function key initiates the simulation phase, which lasts 1-15 seconds on an IBM PC or compatible, depending on the number of representative locations modeled and the specified simulation limits. The program then proceeds to the third phase, output presentation, where the outcome of each simulated fire, the fire frequency and acreage burned by size class and fire dispatch level for the expected value fire year, and expected equipment usage frequencies and projected containment success by fire dispatch level and location are reported. Any of these outputs can be printed, if desired, before cycling back to the data entry/editing phase or quitting the program. All screens in a particular phase can be accessed directly or sequentially via function and cursor movement keys. On-line, screen-specific help can always be summoned by a function key. The data entry/editing phase (Figure 1) and the output presentation phase (Figure 2) together comprise a significantly enhanced user interface over current versions of IAA.

When the simulation phase is invoked, CFES-IAM constructs a dispatch list for each representative fire location with the firefighting resources ordered by increasing arrival time. Then, six representative fires are simulated at each location: one at the 50th and one at the 90th percentile rate of spread for each of three CDF dispatch levels--low,

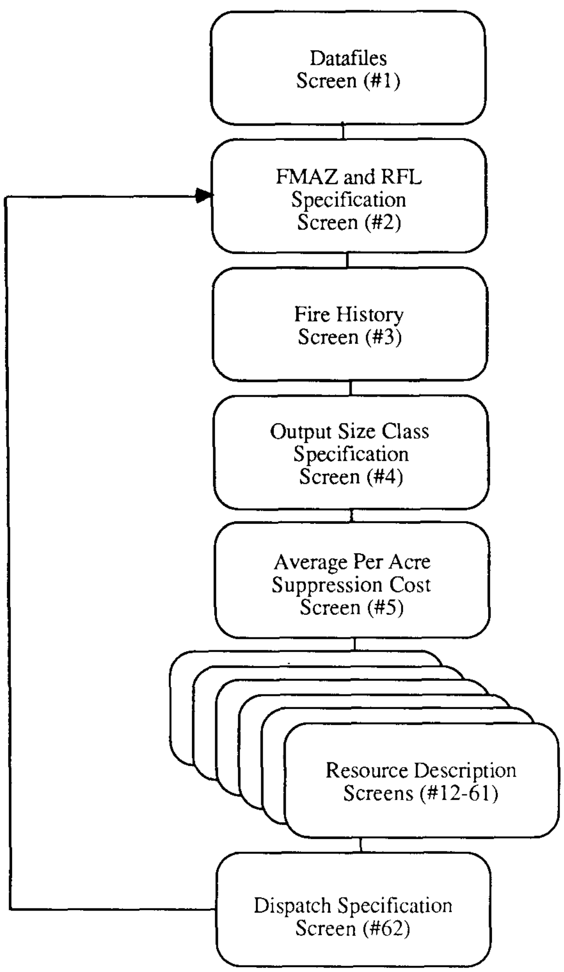

Figure 1--The sequence of screens in the data entry/editing phase of CFES-IAM.

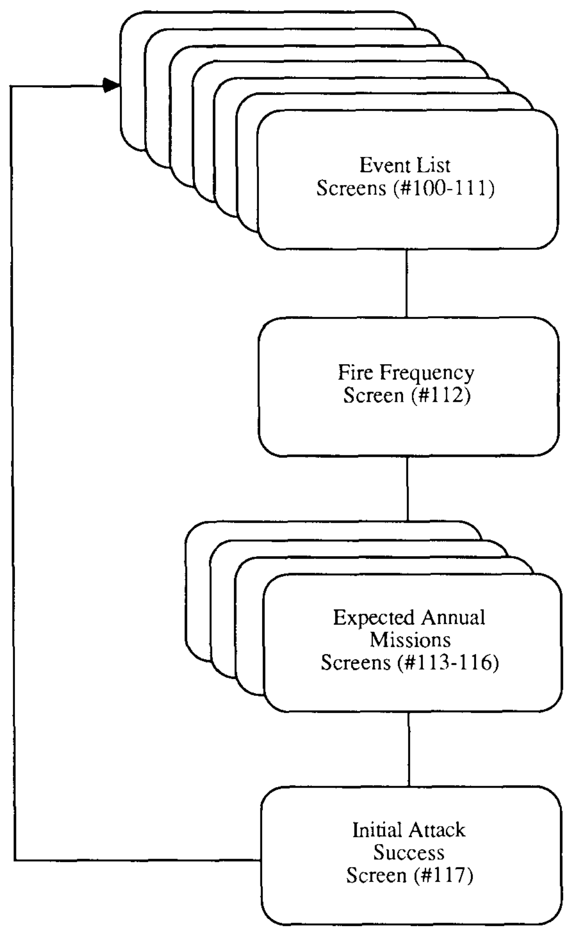

Figure 2--The sequence of screens in the output presentation phase of CFES-IAM.

medium and high. The simulation mechanics are summarized in Figure 3. A more complete description of CFES-IAM and its operation can be found in the CFES-IAM User's Manual (Fried and Gilless 1987).

ANALYSIS CAPABILITIES OF CFES-IAM VERSION 1.11

CFES-IAM was conceived as an interactive, "what-if" simulation tool for California's Ranger Units and Contract Counties. It is intended to be used in conjunction with the judgment of CDF's experienced fire managers, not as a replacement for it. Several types of analyses can be conducted using this version of the program. CFES-IAM can be used to:

1. Evaluate alternative initial attack dispatch policies by simulating the effect of varying the number and type of firefighting resources typically dispatched to different areas under different conditions.

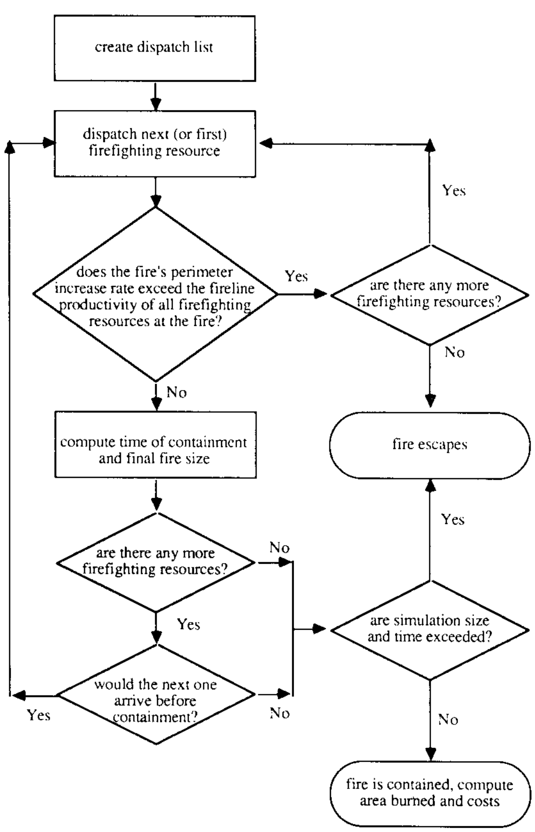

Figure 3--Flow Chart of the mechanics of CFES-IAM simulation of initial attack on one fire.

2. Evaluate alternative stationing of existing firefighting resources by simulating the effect of altering the stationing of existing firefighting resources.

3. Evaluate alternative move up and cover policies and determine critical draw-down points by simulating initial attack only during some critical portion of the fire season.

4. Determine the most effective stationing and utilization of additional firefighting resources by simulating the marginal impact of such resources.

5. Determine how to minimize the damage done to an initial attack organization by the removal of specific firefighting resources by simulating the marginal impact of withdrawing these resources, and by altering stationing and dispatch policies accordingly for the remaining resources.

6. Evaluate the relative effectiveness and contributions of cooperative initial attack forces.

PLANNED ENHANCEMENTS AND IMPROVEMENTS

For effective integration of economic efficiency criteria into CFES a better treatment of large fires and localized zones of high economic risk is essential. The realism of the simulation mechanics should also be improved. The planned enhancements outlined below address these problems.

Instead of utilizing only the expected values (averages) of all parameters, frequency distributions for some could be developed, and CFES-IAM could then be adapted to run in a Monte Carlo mode using these distributions. CFES-IAM would then run repeatedly, sampling randomly from these distributions to assemble the parameters for each run. The expected values of all CFES-IAM outputs would then be revised after each Monte Carlo simulation. When these expected values and their variances stabilized, confidence intervals bracketing the estimates would be calculated and a report printed or displayed. The most likely candidates for stochastic treatment are spread rate, burning index, annual fire frequency, fire size at reporting, fire shape, availability of firefighting resources, productivity of firefighting resources and response times of firefighting resources. This enhancement would improve model realism by ensuring that some of the simulations consider "unusual" events. It would also increase the value of the analysis by explicitly reporting confidence intervals that reveal the level of risk inherent in the alternatives.

An operationally useful, geographic information system approach to defining planning zones is also being considered. Using the CDF's wildland response areas (WRA's: areas of 1 to 50 square miles areas within which the same initial attack forces are dispatched to any fire) as building blocks, WRA's with similar fuels, slopes and habitation densities could be grouped, possibly using an automated cluster analysis technique, to form more homogeneous FMAZ's. This approach could streamline the process of updating CFES inputs to reflect changes resulting from fuel management efforts or residential development. It would also help ensure consistency in the degree of heterogeneity within FMAZ's.

Several enhancements are anticipated for the CFES-IAM to improve the realism of the initial attack simulation. Ideally, CFES-IAM would utilize better fire behavior models. Parallel research (i.e., by a non-economist) is needed to develop improved fuel models that account for the interaction of slope and wind with fuel type in determining fire spread, that more accurately reflect the underlying physical/chemical processes of wildfires, and that better portray the burning behavior of live fuels such as chaparral.

More realistic fireline production rates need to be assembled from the literature, unpublished data, or developed from new data collected in the field. These new values need to reflect how firefighting resources are actually used, and how differences in fuel types, burning conditions and terrain affect production rates. An assumption of the current model is that fireline construction has no effect on the fire shape or spread rate until the fire has been completely encompassed. The fire spread rate could be modified to reflect decreases in the rate of perimeter growth over the duration of the fire where appropriate, based upon field observation of firefighting operations and expert opinion.

The simulation mechanics could also be modified to reflect variation in deployment strategies for ground-based resources under different fire behavior conditions. Ideally, CFES-IAM would match firefighting tactics to the fuel model, burning conditions, topography, resource availability and threats to human life and structures. Initial attack might then be simulated as a direct attack on the head of a fire (or its flanks), or an indirect attack, depending on these factors.

The contributions of air resources to fire containment could also be improved to better reflect the differential effectiveness of air-delivered retardants and water. Of particular concern to the CDF is the current assumption that air resources contribute nothing to containment on fires that spread faster than 40 chains per hour. The authors anticipate analyzing the latest information, collecting some additional data and surveying expert opinion to arrive at more realistic productivity functions for air resources.

Another potential enhancement to CFES-IAM's simulation mechanics concerns fire shape assumptions. Currently, CFES-IAM contains the assumption of an elliptical fire shape for all fires where a longitudinal axis is twice the length of the minor axis. While the length of fireline required to encircle a simulated fire is moderately sensitive to fire shape, the area burned (crucial to the assignment of economic damages and the determination of escapes) is very sensitive to the length-to-width ratio. The BEHAVE model and Rothermel's equations might be used along with the fuel type, wind and slope parameters of simulated fires to endogenously determine more appropriate fire shapes.

Another fire behavior assumption of the current model which could be improved is the length of the build-up phase during which fire spread rates grow to the quasi-steady states predicted by Rothermal's equations. Fire spread rate is currently assumed to start at zero, increase linearly with time and plateau at the predicted steady-state value in between 10 and 60 minutes, depending on the fuel type and burning conditions being simulated. As this seems rather protracted, available data and expert opinions will probably be used to modify build-up phase duration for California conditions.

As part of the CFES analysis process, the economic impacts of large fires (i.e., those that escape initial attack efforts) must somehow be accounted for, both the suppression costs of fighting such fires and the loss of natural resources and property. A first step is to develop California specific estimates of final sizes for fires that are deemed escapes by the initial attack module. One possible approach would be to develop probability distributions of the final sizes of historical fires, and randomly sample from appropriate portions of these distributions to select a final fire size. This way, the final size of escaped fires could be anchored to some extent by fire behavior conditions, and be made independent of the frequency with which fires at a particular intensity level occurred. A paucity of large fire data for individual fire management analysis zones likely would prevent assignment of escaped fire sizes from FMAZ specific distributions. The distributions would probably have to be formed by pooling large fire records statewide from FMAZ's with similar average fire size by dispatch level, fuels, slope, habitation density and historical protection force levels. Presumably, this approach would yield enough data points for any combination of fire behavior conditions to permit the stochastic approach. Other possible approaches would involve gaming techniques and expert opinion. It is unlikely that we will ever be able to simulate large fires, given their complexity and the enormous data requirements that this would entail.

We anticipate that the most influential economic phenomenon in CDF's analysis will be structure loss and that the types and numbers of structures in a management zone, not the vegetation, will determine the efficient level of fire protection. Therefore, we anticipate concentrating our efforts on improving the treatment of localized zones of high economic value at risk within an FMAZ, a concept that must encompass subdivisions, reservoirs and endangered species habitat. To some extent, this can be accomplished through the automation of FMAZ designation and the creation of FMAZ's small enough to be relatively homogeneous with respect to these localized values. In addition, we plan to collect data to help estimate the likelihood of structure loss, given the presence of fire, and to identify the changes in fire protection effectiveness that accompany changes in firefighting strategy related to the presence of structures in the path of a wildfire.

Finally, we anticipate that CFES will never reduce its analysis to a single criterion, like C+NVC, because even the most carefully executed simulation is so distant from reality and the components of NVC that treat nonmarket goods are of such questionable value that an integrative statistic becomes more of a distraction than a tool. CFES outputs will include both costs and value changes, but it will be up to the CDF, and the public to decide whether 20-30 houses saved from destruction justifies a $2 million increase in the fire protection funding level, or whether $100 thousand per annum constitutes a sound investment in preventing the destruction of an endangered species' critical habitat. The authors share the philosophy that when the trade-offs are between apples and oranges, a person makes the decision better than a computer.

REFERENCES

Fried, J.S.; Gilless. J. K. 1987. California Fire Economics Simulator: Initial Attack Module (CFES-IAM) User's Manual version 1.11. Sacramento: California Dept. of Forestry and Fire Protection: Special Publication.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Videodisc/Microcomputer Technology in Wildland Fire Behavior Training[1]

M. J. Jenkins and K. Y. Matsumoto-Grah[2]

Abstract: Interactive video is a powerful medium, bringing together the emotional impact of video and film and the interactive capabilities of the computer. Interactive videodisc instruction can be used as a tutorial, for drill and practice and in simulations, as well as for information storage. Videodisc technology is being used in industrial, military and medical applications for training, sales, education, and information systems.

A project is underway to demonstrate the application of interactive videodisc instruction to wildland fire management by producing a program on wildland fire behavior.

In recent years, fire research has developed a large body of complex information. Proper wildland fire management and use requires a thorough understanding of combustion, fire behavior, fire ecology and history, fire economics, fire effects, and prescribed fire practices.

Large areas of valuable resources and human lives are often at stake during prescribed fire and fire suppression activities, making thorough, up-to-date professional training essential. Because safety is such an overriding concern, adequate training is mandatory to reduce risk.

Most fire management organizations require approximately 40 hours of formal training as a basic prerequisite to any entry level suppression position. The curriculum includes fundamentals of fire behavior, fire suppression, fire organization, tool and equipment use, and safety. Fire behavior is central to this curriculum, and a subject taught by all fire management agencies. Fire behavior has proven to be a stable, well developed course of study; and a complete, multi-level instructional package has been developed by the NWCG, which is the training standard in fire behavior for all NWCG agencies. For these reasons, fire behavior was chosen as the topic of this project.

The project involves using existing fire behavior curricula in an interactive videodisc/computer training system. This disc will supplement existing courses in wildland fire behavior, and will include materials produced by NWCG on introductory, intermediate and advanced fire behavior. In addition, elements from existing courses on fuels inventories, debris prediction, and prescribed fire will be included on the program (Jenkins and others 1985).

The objective of this project is to demonstrate the application of interactive videodisc instruction to wildland fire management by producing a program on wildland fire behavior. This training package will not replace existing instructional materials, but will supplement current training materials. The project is funded by NWCG and is being

[1]Poster paper presented at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

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administered by the Boise Interagency Fire Center. Division of Training, Bureau of Land Management, U.S. Department of the Interior.

INTERACTIVE TRAINING AND INSTRUCTION

Basic principles of interactive design must be clearly understood in order to realize the benefits that can occur through the use of an interactive training medium. To provide useful interaction between the learner and the instructional program, intellectual options should be provided that allow users to actively make decisions and be subjected to their consequences (Bosco 1984). For example, an incorrect calculation of a fire's rate of spread in a given simulation may result in inappropriate tactical response to the incident. Learners make choices, and the system responds, sometimes in surprising ways. An interactive videodisc lesson should allow learners to "create" their own training experience. In this context, it can be defined as: A form of computer and videodisc-based instruction, which allows learners to intervene and make frequent decisions about the content of the lesson and the way it is delivered.

The instructional system responds instantly to learner input by providing relevant, previously designed instructional cues, reinforcement, and feedback segments related to desired concepts, comprised of computer text and graphics, still and motion video, with or without audio. The scope, sequence, rate, style, duration, level, and medium of instruction is, to a large degree, determined by a dialogue between the learner and the system.

The linear. presequenced format of most traditional instructional formats such as texts, workbooks, films, or slide/tape presentations treat all learners alike, and do not allow the learner to actively take part in the choice of sequence or content of a lesson (DeBloois and others 1982). The quality of interactive instruction in combination with the sophisticated video/audio capabilities of television make this medium a potentially powerful tool for instruction.

Interactive video is a powerful medium, bringing together the emotional impact of video and film, and the interactive capabilities of the computer. Development of interactive videodisc instruction has, to a large degree, mirrored computer-assisted instruction or CAI). Like CAI, interactive videodisc instruction can be used as a tutorial, for drill and practice and in simulations, as well as for information storage.

DESIGNING INTERACTIVE VIDEODISC INSTRUCTION

The process of designing, writing, directing, and producing an interactive videodisc/computer lesson in wildland fire behavior is similar to the basic design and production of an instructional film. However, the major challenge is integrating of various media, designing the dynamic relationship between user and the system, and working with a modular, rather than linear medium (Daynes 1982).

INSTRUCTIONAL MATRIX

A content "matrix" for the instructional package in wildland fire behavior was initially developed from a careful analysis of program goals and objectives, existing course materials, learner characteristics, and the various forms of media used within the disc to be selected. This matrix lists the appropriate instructional segments classified by topic and intended learner group in a matrix structure. The matrix thus acts as a "map" which guides the designer in creating the dynamic flowchart which represents the interactive branching training program.

Interactive instruction is designed to be modular and nonlinear, with hundreds of preplanned options available to learners based on prior knowledge of their unique interests, abilities, feedback preferences, primary language ability, and learning styles (fig. 1).

BRANCHING

Videodisc interactivity is made possible through a process called branching. A branching program has alternate tracks for rapid and slow learners, can follow up certain responses in detail, allow learners to see only the materials they need or want to see, test learners on the comprehension of the materials, allow learners to repeat material or to have remedial work when needed, and effectively pose a question without demanding one unique, correct answer. Although branching has been extensively used in computer-assisted instruction, there

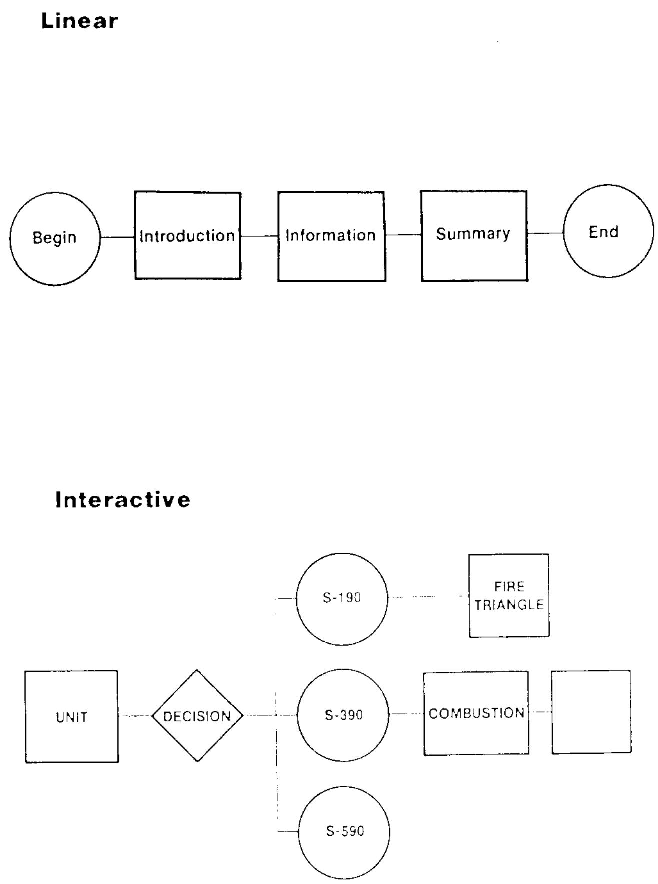

Figure 1--A linear program has a presequenced format, but an interactive program allows learners to make choices.

have been weaknesses in the quality of video imagery and search time for sequences, which have proved to be somewhat disruptive to learning. The introduction of videodisc technology has been an obvious and practical solution to these problems.

FLOWCHARTING

The branching system developed for the instruction must be graphically represented as a flowchart. The flowchart depicts all instructional events included in the wildland fire behavior training program for the various specified audiences. The flowchart shows each instructional frame, both still frames and motion sequences, all branching options, menu driven and under program control, all "help" routines, all test items, and dedicated jump forward and review options.

The procedures used in flowcharting interactive instruction are similar to those used in any flowcharting operation. Symbols are similar, with a few variations that allow for easy identification of the nature of the instructional frame, whether it is still or freeze frame, or motion sequence. A sample flowchart is shown in figure 2 to demonstrate the complexity involved in the development of an interactive lesson in wildland fire behavior.

SCRIPT, NARRATIVE WRITING, AND GRAPHICS

After the major elements of flowchart construction are completed, scripts and narratives must be written, including all text, computer and quiz screens, and test items. Special terms are used to help integrate the various media, and keep track of hundreds of instructional segments which will be used to individualize instruction for the variety of learners who will use the disc. Scripts and storyboards are then drafted and reviewed for content, style, and feasibility; graphics, animation, and special effects are also planned at this time. Formative evaluation and revision is also appropriate at this stage of design.

PRE-PRODUCTION

The preproduction phase of an interactive videodisc is very similiar to that of a film or videotape. However, some steps are unique to the videodisc medium, including mapping the "geographical" layout of the disc, writing of the accompanying computer program, and locating the simple time code numbers for the video frames from the master tape. These steps must be completed before the final production and the mastering of the videodisc (Daynes 1982, Nugent and Christie 1982).

Production details will not be discussed here, as basic production for videodisc is almost identical to that of other media such as videotape or film. Once a master videotape of the training materials is edited and contains all instructional sequences, the tape is sent to one of five mastering houses, where the visual images and audio are transferred onto a videodisc.

HARDWARE AND SOFTWARE CONSIDERATIONS

Interactive videodisc training is oriented toward the development of learning stations for individuals and small groups. Learning environments for interactive instruction can be

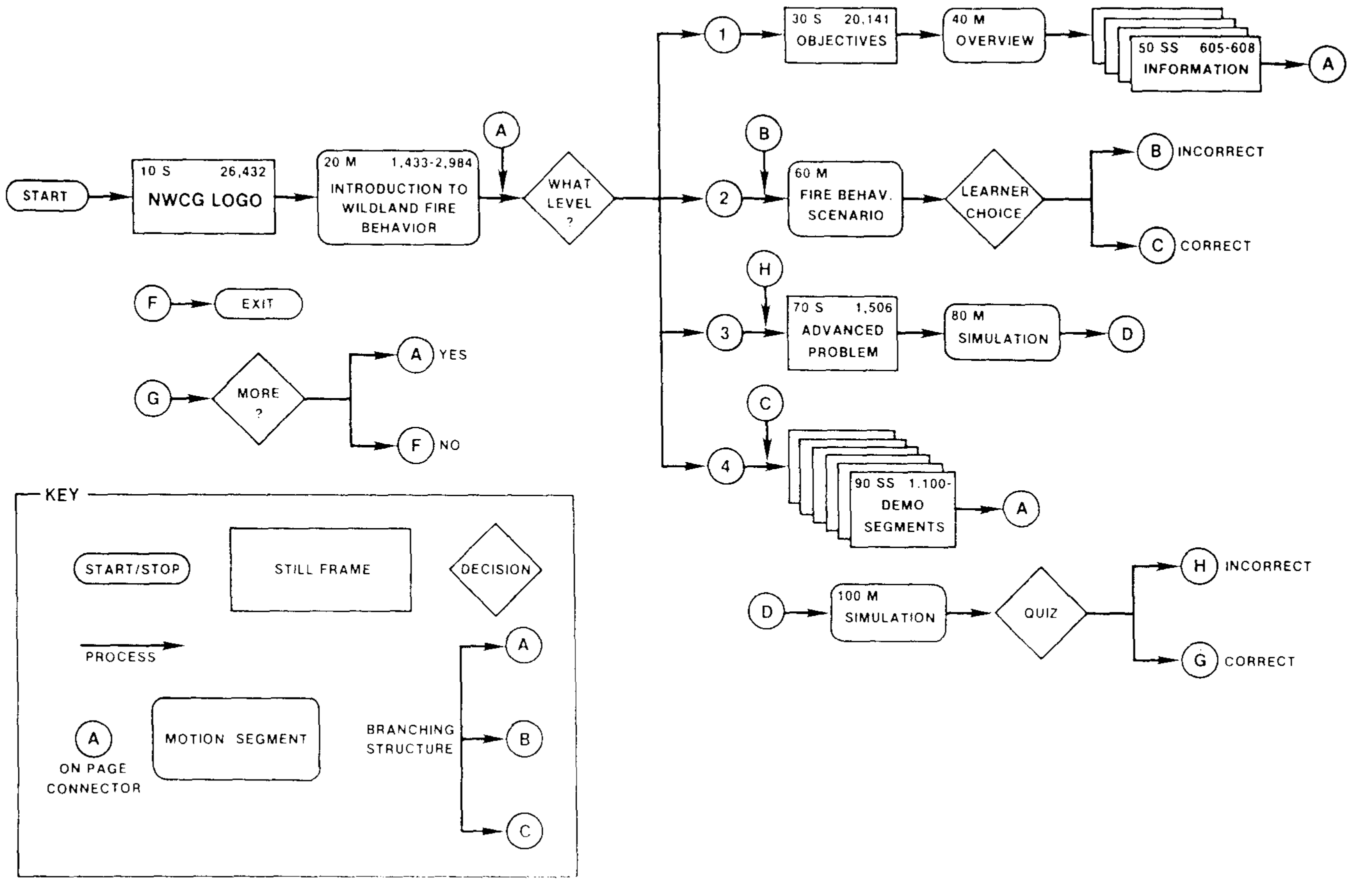

Figure 2--A sample flowchart showing the complexity of the development of an interactive lesson.

any location where an individual or small group can access a computer, which, in turn controls several peripherals, including a videodisc player and monitor (fig. 3). Input to the computer can be through a touch screen, light pen, or keyboard. The video output from the computer, as well as video/audio from the disc appears on a single screen or two separate screens. The delivery system chosen for this project uses one screen, allowing both video from the videodisc, and text over the video, which is generated by the computer. "Windows" of video can be opened to illustrate a point described by computer text or lettering can be written over a video image.

The hardware configuration selected for this project includes an IBM PC computer, Pioneer LD V-1000 video disc player, and a Zenith color monitor. Programming is done using an authoring system called "Quest."

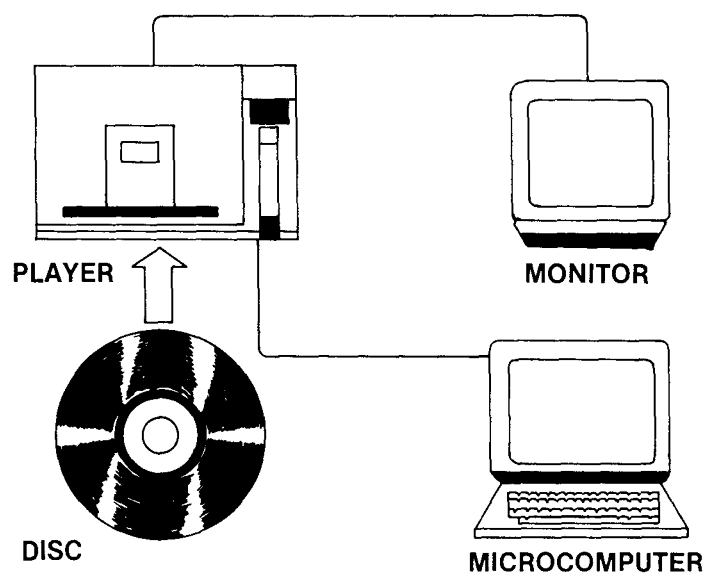

Figure 3--Hardware components of an interactive videodisc/microcomputer system.

EXPECTED BENEFITS

Interactive videodisc technology has proven to be a powerful educational tool, using computer-based learning systems that can display high-quality video imagery, provide rapid access to images, and utilize quality audio. The individualized, self-paced format represented by videodisc instruction focuses on learner needs, rather than predetermined pace and sequence. A learner is able to choose among a variety of instructional options, and learning is directed according to their performance and measurements of their understanding. Interactive videodisc allows learners to have remedial work when needed, or skip ahead if prior mastery is demonstrated.

Other benefits of using interactive systems include these: the use of programs by either individuals or small groups, flexible scheduling of training, the portability and ease of transport of instruction to remote training sites, and the savings of training costs at a fraction of the cost of traditional training methods.

Recent studies in the comparison of videodisc instruction to traditional methods of instruction have shown numerous advantages from the use of interactive videodisc. Such factors such as: savings in actual learning time, higher mastery rate, and favorable response to the medium all prove to be significant factors in the use of interactive instruction. Other cost related benefits include: less time away from the job, reduced travel/living expenses for training, reduction of classroom instructors, and use in remote training stations (Ebner and others 1984, Glenn and others 1984).

Fire behavior training naturally lends itself to the videodisc medium. Because of the huge storage capacity of a videodisc, beginning, intermediate, and advanced fire behavior training courses can be placed on one disc, allowing the learner to seek remedial help when necessary, or go on to advanced material when desired. Fire behavior simulation exercises can also be included, where learners can apply their knowledge of fire behavior in life-like scenarios requiring management decisions. Such simulations are more versatile and "transportable" than previously developed fire simulators, and allow use at small or remote centers, or for individual use for review or training. The incorporation of tutorial lessons, as well as drill and practice, test items, and information storage make interactive videodisc an efficient, space-saving medium for instruction. By providing training at a fraction of the cost of traditional methods (not including development costs), interactive training systems may become a powerful training tool for fire managers and personnel.

REFERENCES

Bosco, J. J. 1984. Interactive video: Educational tool or toy? Educ. Tech. 24:13-19.

Clark, J. D. 1984. How do interactive videodiscs rate against other media? Instr. Innov. 29:1-16.

Currier, R. L. 1983. Interactive videodisc learning systems. High Tech. 3:51-59.

Daynes, R. 1982. The videodisc interfacing primer. Byte 7:48-59.

DeBloois, M.; Bennion, J. L.; Bork, A.; and others. 1982. Videodisc/microcomputer courseware design. Englewood Cliffs, NJ: Educational Technology Publications; 178 p.

Ebner, D. G.; Danaher. B. G.: Mahoney, J. V.; and others. 1984. Current issues in interactive videodisc and computer-based instruction. Instr. Innov. 29:24-29.

Glenn, A. D.; Kozen, N. A.; Pollack, R. A. 1984. Teaching economics: research findings from a microcomputer/videodisc project. Educ. Tech. 24:30-32.

Hon, D. 1982. Interactive training in cardiopulmonary resuscitation. Byte 7:108-138.

Jenkins, M. J.; DeBloois. M.; Matsumoto-Grah, Ky. Y. 1986. Future firefighting--By book or by screen? Training and Devel. J. 39(7): 36-39.

Kindleberger, C. P. 1982. Whither the interactive videodisc? Educ. TV 9:60-65.

Nugent, R.; Christie, K. 1982. Using videodisc technology. Video Syst. 2:16-2l.St. Lawrence, J. 1984. The interactive videodisc: Here at last. Elec. Learning 4:49-54.

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An Expert System for Designing Fire Prescriptions[1]

Elizabeth Reinhardt[2]

Abstract: Managers use prescribed fire to accomplish a variety of resource objectives. The knowledge needed to design successful prescriptions is both quantitative and qualitative. Some of it is available through publications and computer programs, but much of the knowledge of expert practitioners has never been collected or published. An expert system being developed at the, Forest Service's Intermountain Fire Sciences Laboratory in Missoula, Montana, uses artificial intelligence programming techniques to integrate this diverse information, and interpret it for application, and to recognize skilled practitioners as an important source of knowledge. These artificial intelligence techniques include rule-based inference and frame-based inheritance.

Expert systems are computer programs that exhibit expert performance. They accomplish a task usually performed by a person with expertise in a particular area, and they are designed to accomplish the task in a manner similar to that used by the human expert. They are able to explain the conclusions they draw. This paper describes the structure of a prototype expert system to aid in the design of fire prescriptions. The system is being developed at the Forest Service's Intermountain Fire Sciences Laboratory in Missoula, Montana. A demonstration prototype should be available by the end of 1987.

THE PRESCRIPTION DEVELOPMENT PROCESS

Prescribed fire is used to accomplish a variety of wildland resource management objectives. To use prescribed fire successfully, a manager first needs to determine the fire effects that best lead to accomplishment of these resource objectives on the site to be treated. Fire effects include fuel consumption and vegetation mortality. The manager then needs to define the constraints limiting the application of fire. These include smoke production, site protection, and fire control. Next, the fire treatment that will produce the desired fire effects while staying within the constraints must be specified. Finally, the manager needs to determine what burn conditions produce the specified treatment. This is the process of prescription development.

The information a manager uses in this process is extremely variable, both in quantification and availability. Some aspects of this problem, such as fire behavior, have been carefully described with mathematical models, while others--such as plant response--are at present best described with qualitative statements. Some of the available information is widely applicable, while some is site specific. Finally, research results document some of the information, while other information comes from the calibrated judgment of experienced practitioners and may not be published or widely available.

[1]Poster paper presented at the Symposium on Wildland Fire 2000, April 27-30, 1987. South Lake Tahoe, California.

[2]Research Forester, Intermountain Fire Sciences Laboratory, Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Missoula, Montana.

THE ROLE OF THE EXPERT SYSTEM

The expert system will aid in prescription design in several ways. First, the system will walk the user through the process of prescription design, much as an expert might. This will help inexperienced users understand the process. For an experienced user it will simply provide a logical flow through the problem.

Next, the expert system will serve as a centralized source of information needed by managers to design prescriptions. Research results, currently scattered in a number of papers, will be integrated into the system so that a manager can use them without having to dig through files and figure out just which paper is most appropriate to the situation at hand. Heuristic knowledge, or rules of thumb, of experienced practitioners will also be stored in the program and thus made widely available. This kind of knowledge or expert judgment is an important resource to prescribed burners, and currently there is no formal mechanism for transfer of this knowledge.

The expert system will query the user about the prescribed fire project in order to produce a prescription tailored to the site and the resource objectives of the project. All intermediate conclusions of the system will be displayed to the user for verification or possibly for adjustment. In this way the user's expertise is included in the final prescription.

The system will recognize and point out conflicts to the user. These conflicts are combinations of objectives and constraints that are so restrictive they cannot all be met with prescribed fire.

Finally, the system will provide explanations of its conclusions. This will help a user learn from the system, and it will increase the user's confidence in its results.

In some fields, expert systems perform more consistently and accurately than human experts. These systems are usually restricted to answering a specific set of questions that are well understood. This system is expected to perform more at the level of an "expert assistant." In part this is because of the breadth of the field, and in part it is because the state of knowledge in the field is still developing and incomplete.

THE STRUCTURE OF THE EXPERT SYSTEM

The generalized structure of the system is illustrated in figure 1. Information is stored in three forms: as rules, in frames, and as quantitative models. The computer program that processes this information, the inference engine, is independent of the fire prescription domain. It manages the information and uses it to draw conclusions. Keeping the processor separate from the information provides a flexibility and expansibility not available in conventional procedural programming. The user interface insulates the user from the programming details of the system. The user may provide input or query the system through the user interface, and solutions or explanations are passed from the system to the user through the user interface.

Rules

A fundamental form of knowledge representation in most expert systems is a rule. Rules are meant to reflect the way people think about problems. Knowledge is broken into small, manageable chunks that are self-explanatory. A rule is simply a statement of the form: If (conditions) then (conclusion). Rules are processed by "chaining." The processor seeks sequences of rules such that the conclusion of one rule

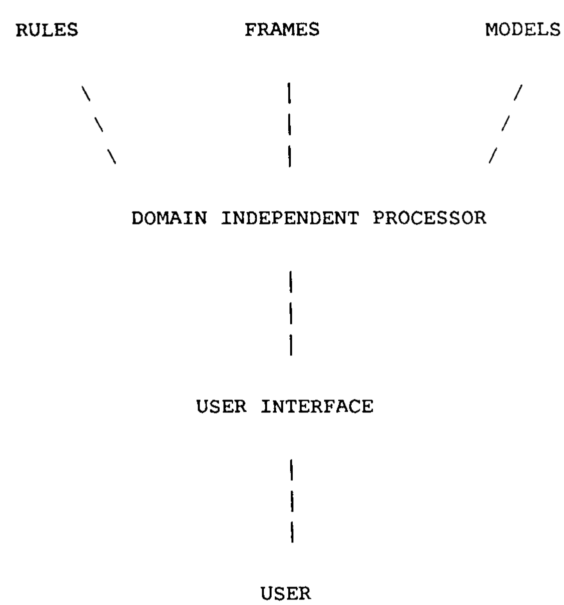

Figure 1. Generalized structure of the expert system

matches the condition of another. These sequences allow inferences to be drawn and; this is why the processor is sometimes known as an inference engine.

Chaining may occur in either a backward or forward direction. Backward chaining may be thought of as hypothesis testing: A hypothesis is set forth, rules supporting this hypothesis are sought, the conditions of these rules may be known facts or new hypotheses supported by other rules, until finally either known facts that support the rules are found, or the hypothesis test fails. Forward chaining is more exploratory in nature: A fact is set forth, rules are found that draw conclusions (new facts) from this fact, and the process is repeated until no more relevant rules are found.

Rules allow automated processing of qualitative information. Conventional computer programming techniques deal with numeric data better than with words. Yet much of our understanding of natural processes is not of a numeric nature. Rule-based reasoning helps bridge the gap between computer processing and human thought.

Frames

Frames provide the dynamic data structure of the system. A frame is a data object that exists in a hierarchical network of objects. It may inherit characteristics from objects that are higher in the hierarchy and pass characteristics to objects beneath it. The structure of an individual frame follows this form:

Object:
  Attribute Value
  Attribute Value .....

Values may be numbers, words, or computer code.

An example of a frame in the prescription design system is a frame to hold information about duff:

Duff
  preburn depth_______
  resource needs________
  consumption objective________
  consumption constraint________
  best consumption model_________
  prescribed moisture content_______

This frame is empty at the beginning of a run, and gets filled as rules are processed. Other frames are used to store information and do not change in the course of a run. In fact, rules are themselves stored in a specialized kind of frame.

Quantitative Models

Much of the emphasis in expert systems literature is on qualitative reasoning. However, quantitative models are also an important resource for prescription design and must be integrated with the rules and frames. The expert system will use quantitative models just as an expert practitioner accesses a computer program or does some quick figuring on a calculator. Knowledge about how to use these models is stored in rules and frames and can be processed by the domain independent processor, shielding the user from the details of accessing and using them.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Foam as a Fire Suppressant: An Evaluation[1]

Paul Schlobohm and Ron Rochna[2]

Abstract: The ability of fire suppressant foams to improve ground-applied fire control efforts was evaluated. Foaming agents and foam-generating systems were examined. Performance evaluations were made for direct attack, indirect attack, and mop-up. Foam was determined to suppress and repel fire in situations where water did not. Cost comparisons of mop-up work showed straight water to be significantly more expensive than foam. Foam will replace all current water applications and present new suppression opportunities to the fire management community.

The Bureau of Land Management (BLM) is evaluating the effectiveness of foam as a means of controlling fire. The impetus for this study can be described by the reality of current ground-applied fire control efforts. Wildfire suppression capability is limited where water is scarce and real property values are threatened. Prescribed fires are often difficult to contain. Time-consuming mop-up reduces further burning opportunities.

[1]Presented at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

[2]Fire Management Specialists. Boise Interagency Fire Center, Bureau of Land Management, U.S. Department of the Interior, Salem, Oregon.

THE CONCEPT OF FOAM

The concept of foam is not new, but the limited use of foam in wildlands warrants a review of its capabilities. Foam extends the life and effectiveness of the water it contains. Foam reduces the surface tension of water molecules enabling greater penetration of the water. Soap-based foam opens the waxy coating of green vegetation, further enhancing wetting ability. Foam inhibits water flow, allowing more of the water applied to be used for cooling. As foam, water becomes a reflective, insulating blanket (Everts 1947, Godwin 1936).

FOAMING AGENTS

Foam systems, as recently as 1985, relied on foam-making substances not specifically designed for fire suppression. Pine soap or soap skim, popularized by the Texas Snow Job, is a derivative of the paper-making process. Household dish soap was also used because of its availability (Ebarb 1978).

Since 1985 foaming agents designed for wildland fire suppression have been available. These products combine relatively stable bubble structure, improved wetting ability, and vapor suppressants. They provide the capability of instantaneous extinguishment, construction of an impenetrable barrier to fire, and reduction of mop-up time.

FOAM GENERATING SYSTEMS

Foaming agents can be used by a variety of means. Synthetic foaming agents have sparked new interest in the foam generating systems made popular by pine soap. Compressed air foam systems (CAFS) have been modified with centrifugal pumps and metering devices, and enlarged with 40 cubic feet per minute (cfm) or greater air compressors. Air aspirating and conventional water systems also have applications for foam.

Compressed Air Foam System

Foam is produced in the CAFS by mixing compressed air and solution at equal or nearly equal pressures and pumping the mixture through one of three forms of agitation. Hoselays longer than 50 feet (of 1 inch diameter) provide enough space for air and water to mix into foam. Scrub chambers, tubes filled with obstructions, force air and water into foam in 1-2 feet. Specialized nozzles combine compressed air and atomized solution as they leave the nozzle. Hoselays are the most common agitation method and this discussion will concentrate on their features.

Compressed air systems that pump foam through the hose flow water at less than normal rates. A 1-inch nozzle may flow 12 gallons per minute (gpm) of water as foam at 150 pounds per square inch (psi), with a discharge distance of 85 feet. Water is expanded about 10 times at agent mix ratios of 0.2-0.3 percent. CAFS has the unique ability to change foam consistency by changing water flow rather than mix ratio.

Extra equipment required for the CAFS includes an air compressor and full flow ball valves. Compressor size is dependent on need. Generally, 2 cubic feet of air is necessary for every gallon of water to create quality CAPS foam. The ball valves are used as nozzles to shut off the foam flow.

Air Aspiration System

Foaming agents have also initiated the production of a wide range of air aspirating or expansion nozzles. Low and medium-expansion nozzles produce quality foam. Low-expansion nozzles are most common. They flow 10-30 gpm at 150 psi and discharge a stream 30-70 feet. The air aspirating system pumps solution through the hose and creates foam at the nozzle. Air is drawn into the nozzle when the solution is atomized and passed through a pressure gradient. Water is expanded 5-10 times with agent mix ratios between 0.3 and 0.4 percent.

Conventional Water System

Conventional water apparatus creates the third type of system with which a foam agent can be used as a wetting, extinguishing solute. Through all apparatus from turbo jet to sprinklers to bladder bags, bubbles will form froth due to low agitation. With the surfactant in the water, wetting and extinguishing will increase over straight water.

Special Equipment

Technology offers improvements from conventional equipment for mix methods, hose types, hoselays, and nozzles. The inefficiencies of batch mixing concentrate and water are overcome with eductors of proportioners. Eductors also make possible the use of foam when the sole motive force is a water pump. A portable pump, for example, can draw concentrate into the hose as it pulls water out of a stream. Proportioners, which pump concentrate as desired into the water line, have the accuracy and dependability necessary to be integral engine components.

Hose types are important when foam is pumped through the hose, as in CAFS. Durable woven rubber hose is used to avoid kinking. Any restriction in a hoselay will break down bubbles thus significantly reducing foam quality and discharge capability. Hose that is porous or has an irregular lining will disrupt foam flow and reduce discharge performance (table 1).

Table 1--Hose characteristics important to foam flow.

Hose type	Resistance to Kinks	Resistance to Fire	Porosity w/ Foam	Resistance to Flow
Synthetic	poor	poor	high	high
Cotton	fair	fair	low	medium
Rubber	excellent	excellent	none	low

Hoselays for the CAFS can differ depending on application. Usually, foam barriers are applied with one or two nozzles. Since foam is compressable, hoses are easily clamped and extended. Hoses filled with foam do not exhibit all characteristics of hydraulics. Greatly reduced head pressure enables foam to be pumped significantly farther above the pump than water.[3]

Nozzles vary in performance for aspirated and compressed air systems. Low expansion air aspirated nozzles range in performance for 1.5 inch hose from 7 gpm and and 25-foot discharge to 26 gpm and 70-foot discharge at 150 psi. At 35 gpm and 150 psi, a 1-inch CAFS nozzle has a maximum discharge of 70 feet and a sustained discharge of 55 feet; and a 1-3/8 inch nozzle; has a discharge of 90 feet (maximum) and 70 feet (sustained).

APPLICATIONS

The applications phase of the project directly evaluated, fire control potential of foam in the field. Where possible, foam was compared with to water performance. Evaluations were on prescribed fires and wildfires throughout the western United States.

Direct Attack

Visual evaluations of foam's extinguishing capability were made. Flames burning in light flashy ground fuels, tall snags, pitchy stumps, red slash concentrations, and desert sage were extinguished instantly with foam. For example, two light engines worked the flank of a range fire. The engine using air aspirated foam never had to turn around for rekindled flame. This engine's pumping time was 1/3 greater than the water engine's. Some of the flank extinguished by the engine using water started burning again (Carriere 1986).

The compressed air foam system has great extinguishing capability in part because foam can be compressed indefinitely in the hose. The ball valve can be shut off without risk of bursting hose. This creates back pressure in the hose which, when released, produces a fine-bubbled mist and long discharge distances (fig. 1). The fine-bubbled mist is unique to the CAFS. When released the mist puts on a cooling, suffocating performance that has been compared to halon gas. Together with initial discharge distances of up to 75 feet with 1-inch hose, the mist gives the firefighter a deluge initial attack capability. Many prescribed burn spot fires have been extinguished by merely opening and closing the ball valve.

After the initial, fine-bubbled surge, foam produced becomes thicker. It forms large masses of bubbles, which cling together. This clinging property is also an important extinguishing feature. Foam can be lofted onto flames, the clinging bubbles forming a vapor-suppressing blanket that also separates oxygen from flame. Because it exhibits low head pressures, foam can be injected into the bottom of a burning snag to extinguish fire burning within. The foam will fill any accessible cavity and suffocating the fire.

Protective Barrier

Applications of foam for protection include prescribed burn boundaries, fuelwood piles,

Figure 1--Fine-bubble mist is expelled during initial discharge from compressed air foam system.

[3]Data on file, Department of the Interior. Bureau of Land Management, Boise Interagency Fire Center, Boise, Idaho.

snags (fig. 2), wildlife trees, fragile sites, and backfire wetlines. Twenty firelines adjacent to prescribed fire units have been pretreated with foam. The foam-treated areas adjacent to firelines ranged from 300 feet to 1500 feet in length; width (25-100 feet) and depth (0.25-2 inches) depended on the foam generation system and site conditions. The time between application and ignition ranged from 0 to 45 minutes. Spotting beyond the foam lines occurred on occasion, but no foam line was crossed by moving fire.

Two examples of foam as a barrier to fire occurred on the Toad Creek unit in western Montana. Fuel loading was 100 tons per acre of fuel model 13 lodgepole pine/subalpine fire (Pinus contorta var. murrayana Engelm/Abies lasiocarpa) logging slash. The prescription of 40 percent relative humidity, 70°F temperature, and light favorable winds (1-4 miles per hour) was met at 2000 hours. Nevertheless, running flame lengths were 3-20 feet high, and the fire crowned to 60 feet.

Figure 2--The compressed air foam system is capable of protecting tall snags.

In the first example, a 150-foot by 10-foot by 1-inch foam line was placed across one 1/2 acre corner of the unit. No tools were used, and no fuel was removed to construct this line. The unit's test fire was lit in the corner. The fire ran quickly to the poles standing adjacent to the line, crowning and producing firewhirls. When the fire reached the foam line, flames leaned over the line, but the fire's forward progress stopped. Time elapsed from foaming to fire contact was 2 minutes.

Lighting of the rest of the unit continued across the foam line. The line was exposed to heating on both flanks for about 5 hours. Inspection on the following day showed that the line was intact, with green vegetation and fine fuels throughout. Two logs greater than 8 inches in diameter which had burned through the line from both ends were the exceptions.

In the second example, a 1400 foot foam line was placed outside a cut fire trail in an adjacent timber stand. Foam was applied 100 feet wide, 75 feet into the canopy, and 1-2 inches thick. Application was 5-15 minutes prior to ignition of the adjacent portion of the unit. Two people created this line with one 1-inch hose. Application time was 5 1/2 hours. Fire behavior remained extreme, with long duration, high flame length fire tossing firebrands into the treated stand. Personnel familiar with burning under these conditions expected the fire to escape. The width of the line prevented most firebrands from starting spot fires. One spot that did occur was extinguished with foam from 60 feet away.

Mop-Up

Performance and costs of foam and water were compared directly during mop-up operations. Personnel involved were not informed of the comparison to avoid any changes from standard instructed procedure. In each case, the foam crew was mopping up with foam for the first time.

One comparison was made during mop-up of a wildfire in felled and bucked Douglas-fir (Pseudotsuga menziesii) timber. One 4-person foam crew using 2 nozzles completed 100 percent mop-up of 5 acres in 3 hours with 7700 gallons of water. Nearby, on 5 acres of the same fire, this productivity was equalled by two 20-person crews using 24 nozzles and approximately 55,000 gallons of water.

The foam crew used 15 gallons or $225 worth of foaming agent based on a 0.2 percent mixture and a price of $15 per gallon. Assuming that the average salaries are $7 per hour for the foam crew and $5.50 per hour for the water crew, the foam operation cost $309 for both labor and foaming agent; the water operation cost $660 for labor only.

The second comparison occurred during mop-up of the Toad Creek unit. A 5 person foam crew mopped up 100,000 square feet in 4 hours. A 25 person water crew mopped up 25,000 square feet in the same time. Both crews had an unlimited water supply. Total water flow for the foam crew was 30 gallons per minute. Again, 15 gallons of foaming agent was mixed. Using the same wage assumption as in the first comparison, the foam operation cost $365; the water operation cost $550 (Moinber 1987)[4].

Foam application technique for both comparisons was designed to let the foam do the work. Foam applied was wetter than the protective foam type. Foam was spread out so that it penetrated and cooled, while the operator moved on. Extra attention to hot spots was given only when heat was well below the surface.

DISCUSSION

Foaming Agents

Of all the types of foaming agents evaluated, the relatively new synthetic products made specifically for Class A fuels are preferred. The 3.0 percent mix ratios for pine soap are 10 times greater than those for synthetics. Preliminary laboratory tests have shown pine soap to be an inferior wetting agent. Common dish soap lacks vapor suppressants and durability. The price of the new agents has continued to drop as the demand for them has increased. Some users have experienced 25 percent reductions in suppression costs despite the $12-15 per gallon prices.

The notion that water is free is a fallacy. The BLM fights most of its fires miles from water sources. Twelve dollars can turn 500 gallons of water into 5000 gallons of effective water as foam.

Foam-Generating Systems

Purchasing requirements vary significantly with the three generating systems evaluated. Foaming agent alone will give an improved wetting agent with conventional apparatus.

As a minimum initial investment in equipment, air aspirating nozzles will assure quality foam production, especially for protection and mop-up. Long term use of this system is appropriate only if the consistent high use of foam is more tolerable than a high initial investment for the compressed air system.

The CAFS generally requires the greatest initial capital outlay, primarily the air compressor, as well as a retrofitting or new engine package. However, CAFS can be assembled on-site from inexpensive components such as rented trailer air compressors, readily available plumbing, and an existing water pump. The high initial cost is quickly returned by increased capability and performance, and reduced volume of foaming agent required.

Applications

The success of foam performance in the examples given can be attributed to two factors. First, the combination of synthetic foaming agents and the compressed air foam system creates a powerful tool for fire suppression.

Second, proper training is necessary to ensure success. Foam can fail and if its properties and uses are not understood, it will. Foam should not be considered a cure for every fire situation, it is simply a very useful tool.

Foam must be of the appropriate consistency: wet, dripping, or dry. It must be applied for the appropriate effect: lofted for intact, clinging, and smothering bubbles; pressure impacted for broken, wetting bubbles.

Safety precautions should be understood when using foam. Foaming agents are mildly corrosive to skin and eyes, and protective gear is recommended. The high-pressure lines of the CAFS should be operated with caution. Valves

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[4]Data on file, Department of the Interior, Bureau of Land Management, Salem District, Salem. Oregon.

must be opened slowly to prevent nozzle kickback and hose whiplash.

THE FUTURE

Over the past 2 years foam has developed into a tool for the future. The full potential of foam has yet to be realized. In fact, the technology of Class A foam firefighting is expanded beyond Class A fires. Cost-effective, successful applications have been demonstrated with hydrocarbon fires, vehicle fires, and structure fires. Methods of delivery are also expanding to fit different needs and resources.

The wildland-urban interface protection program may have the most to gain from foam development. Research must increase our understanding of foam processes. Training in application techniques must begin. The days of fighting fire with unrefined water are numbered. Water has served us well in fire suppression over the years. As we move into the 21st century, water will serve us even better as foam.

REFERENCES

Carriere, A. Fire Management Officer, Lakeview District, Bureau of Land Management. U.S. Department of the Interior. [Telephone conversation with Ron Rochna]. 20 July 1986

Ebarb, P. 1978. Texas snow job. Fire Management Notes 39(3). Washington DC: U.S. Department of Agriculture; 3-5.

Everts, A.B. 1947. A dual purpose hazard reduction burner and foam unit. Fire Control Notes 8(2,3). Washington DC: U.S. Department of Agriculture; 10-12.

Godwin, D.P. 1936. Aerial and chemical aids. Fire Control Notes l(l).Washington DC: U.S. Department of Agriculture; 5-10.

Moinber, J. Forester, Simpson Timber Company, Eureka, California. (Personal Conversation with Ron Rochna] 5 May 1987.

Futuring Group Reports

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

The Futuring Process[1]

Delmer L. Albright[2]

Abstract: "Futuring" is becoming a widely accepted approach to organization management and goal setting. Strategic planners for the United States military as well as the Forest Service. U.S. Department of Agriculture, and the California Department of Forestry and Fire Protection, use Futuring to develop action plans and organizational directions for their agencies.

Futuring is a participative process that brings together several individual ideas into a collective group perspective of a preferred future. Working in small groups with the assistance of trained facilitators, people with different ideas and backgrounds use futuring to develop a Vision of a desired or preferred future.

The Vision inspires commitment from the group, guides daily decisionmaking, provides interim strategies, and suggests behavioral changes necessary to accomplish the Vision. The Visions and Strategies developed at the Symposium on Wildland Fire 2000 gave attendees something to take back to their own agencies for implementation.

[1]Master Facilitator/Conference Staff, Wildland Fire 2000; Presuppression Division Chief, California Department of Forestry and Fire Protection. San Andreas. California.

PROCESS OVERVIEW

The futuring process for Wildland Fire 2000 was designed to develop a Vision of the future, and to outline a few Strategies for achieving the Vision.

Conference attendees were divided into nine topic-oriented groups, and were given the following objective:

> "Through facilitated small groups, develop 10 Key Trends and 3 Key Visions that describe a preferred future in each of 9 topics."

At the close of the conference, each small group gave a presentation of their Key Visions and Strategies.

DEFINITIONS

Trends are political, social, economic and technological factors affecting wildland fire today... the direction things are heading. Trends for Wildland Fire 2000 were established during the early stages of the conference by the speakers.

Key Trends are the most significant of the trends as determined by each small group.

Implications describe what the Key Trends mean to the group... So what?

The Vision is a description or written picture of a preferred or desired future that is attainable, and serves as a guide to interim strategies, behaviors, and decisions.

Key Visions are the most significant, consolidated versions of Visions developed by individuals in the group.

Strategies are broad, general approaches to attaining a Vision or part of a Vision.

MODEL SPECIFICS

Futuring begins by establishing the foundation of the model--the trends--affecting the organization. Then a Vision of the preferred future is developed. Each Vision is then given a pathway to implementation through the development of Strategies. Each small group in Wildland Fire 2000 went through specific steps of the process model shown below.

1. Group Introductions.
2. Discussion of the Trends as noted in the conference presentations.
3. Identification of 10 Key Trends.
4. Discussion of the Implications of the Key Trends.
5. Development of each individual's Visions of a preferred future based on the group's topic and Key Trends.
6. Identification of 3 to 5 Strategies for each of the Key Visions.
7. Appointment of a spokesperson to present a summary of the Key Visions and Strategies.

All products of these steps were recorded on flip charts by the Facilitator Team.

CONCLUSIONS

Planning has been described as a process to bring the future to the present so something can be done about the future before it gets here. Futuring is the ultimate planning tool. It provides a collective picture of a desired and preferred future, describing a Vision that serves as a beacon attracting individual actions toward the same end.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Education and Training -- Research and Development: Report of Futuring Group 1[1]

Public agencies involved in natural resource management and fire protection will face many challenges over the next few decades, including decreasing real budgets, lower staffing levels, increasing responsibilities, expanding technologies and a more sophisticated and demanding public. In addressing these challenges, resource managers must be prepared to enter a new phase of interagency cooperation in which authority and responsibilities are pooled for more efficient utilization. Closer liaison must also be established with higher education to insure both the development of needed technologies and the production of a skilled employment pool.

TRENDS

The trends identified by the group were either factors internal to fire management (intra-agency management and policies) or external factors (public needs, demands, and expectations). Although all participants expressed similar concerns, it was evident that federal agencies, particularly the Forest Service U.S. Department of Agriculture, were under the greatest internal and external pressures.

Funding

Intra-agency trends are more directly related to reduced funding and decreased staffing. At the same time, existing staffs are becoming fragmented through increased field specialization, often resulting in poor communication and conflicting goals. The trend toward budgeting austerity is also effectively reducing salaries, making natural resource management careers less appealing.

[1]Prepared at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

Education

Public expectations of land management and fire prevention agencies are increasing and will continue to do so. These expectations are not only the result of the increasing--and increasingly diverse--uses of public lands, but also of greater public sophistication on environmental issues. Public agencies are therefore expected to provide more with less, yet do it better, than ever before. As a result there is an increasing need for agencies to educate the public, not only as to their management activities, but their underlying rationale as well.

The need for multidisciplinary "generalists" is becoming more important. This trend is the result of two separate processes. First, the previously mentioned trend towards staff specialization has reduced the potential for cross communication, even within the same agency. While specialization seems inevitable, there is an increasing need for individuals with academic training in multiple fields to bridge this communication gap. Secondly, in the face of reduced staffing levels, the need for specialists able to perform other tasks is becoming critical.

Training

The inconsistency in training of personnel for prescribed fire management is a developing problem. Diverse local, state, and federal agencies are creating highly individualized training programs with little consistency in the scope of subjects or detail. At best this results in difficulty for land use agencies seeking to cooperate fully on prescribed burn programs of other agencies.

A model of coordinated training for prescribed fire managers can be found in the federal "S" series of courses for fire suppression. However, this training, offered as individual classes with no overall coordination, increasingly drains available staff time and (travel) resources. Individuals required to take more than a single "S" course may wait months between classes, and may have to travel widely from course to course.

Research and Development

The technological and theoretical advances in resource management expand the options available to manager confronting real problems. As these (often expensive) tools are developed there typically is a corresponding demand to use them in management programs. Conversely, the commercial, residential and recreational development of America's wildlands act to limit the options available to resource managers to those suitable for use in and around the public. Also, resource programs become much more expensive and labor intensive under these conditions. The need exists for the development of new-management techniques designed for efficient use within the urban/wildland interface.

Past research into fire behavior and suppression techniques has proven invaluable at increasing the ability of public agencies to attack fires efficiently and effectively, yet the opportunity to continue this research in the future appears to be decreasing. This downward trend in fire behavior research is a serious problem, particularly in the face of increased fire starts, wildland urbanization and decreasing staff levels for suppression activities.

Key trends are these:

- Decreasing number of young people educated in natural resources entering the work force.
- Increasing responsibilities in time of decreasing available money.
- Increasing need for people trained in multiple disciplines.
- Increasing public scrutiny, resulting in increased emphasis being placed on public education (by management).
- Increasing public expectation of resource agencies.
- Increasing public awareness regarding the environment.
- Lack of perception by the public of the high cost of resource management.
- Increasing use of prescribed burning for fuels management.
- Increasing urbanization of wildland, resulting in a decrease in management options.
- Decreasing emphasis on fire research.
- Increasing fire occurrence.
- Decreasing budget allocations for fire protection, including prevention, suppression and training.

VISIONS AND STRATEGIES

While the visions all differ, one common thread is found in their respective strategies: the need for legislative support. The development of new policies for the management of public lands, and the necessary funding and staff support to implement them require obvious legislative action. More profoundly, the members of the group expressed a sense that government decision makers are either unaware of, or unresponsive to, the needs of resource managers and fire suppression personnel. Moreover, the administrators of public resource agencies seem unwilling to argue in favor of these needs during the budgetary process.

Research

Vision

Fire research would be supported at all levels, and would produce what users need.

Strategies

- Establish a National Director as resource coordinator, with interagency involvement.
- Identify user needs and issues.
- Develop legislative support.
- Increase communication between users and researchers.

Discussion

This vision not only reflects concern over the reduction of the Forest Service fire research program, but also over the tendency in academia to concentrate on research that does not meet the immediate and pressing needs of fire suppression personnel. A key aspect of the vision is that no one agency is singled out as being solely responsible for fire research. Instead, the call is made for a coordinated effort involving all levels of government (local, regional, state and federal) and higher education.

Training

Vision

A standardized prescribed fire curriculum and qualification/certification system would be developed and adopted by all resource management and fire agencies.

Strategies

- Assign one full time person from each agency as a fire management training specialist to develop curriculum.

- Cooperate with academic institutions.

- Increase communication, cooperation and coordination between all agencies. including state and local.

Discussion

Currently, each agency using prescribed fire as a management tool has developed its own training program. These programs vary widely in content and scope, with a resulting concern between agencies about the qualifications of each other's fire managers. Also, prescribed burning is entering the area of being a true profession, and practitioners feel the need to formally define it as such.

Vision

Fire management training would meet proficiency standards in a timely and cost efficient manner.

Strategies

o Secure interagency commitment to improve training.

o Establish fire academes to provide quick cost efficient methods to train fire management personnel to desired levels.

Discussion

This vision reflects the concern of the group that fire training places a significant burden upon management due to the lack of sequentially arranged coursed offered at a central facility. In some cases, it may take 2 years to train personnel to desired levels, often by courses at widely separated facilities.

Education

Vision

Policy makers, resource protection agencies, and the public cooperate so that potential for loss of life from wildfire does not exist at the urban/wildland boundary.

Strategies

- Educate the public concerning resource management problems/solutions.

- Channel public awareness toward legislative action.

- Encourage enforceable land use planning and building codes.

Discussion

Central to this vision is the concept that--through thoughtful land use planning, construction codes, and public education--the potential for loss of life due to wildland fire need not exist. The current threat to private citizens living near the wildland/urban interface is largely the result of poorly considered development and weak zoning regulations.

Prevention

Vision

There would be a fire prevention program based on economic benefits, rather than traditional "Smokey-the-Bear" arguments.

Strategies

- Encourage fire prevention research.
- Establish a means of inter-agency support for:
  - --public education
  - --enforcement
  - --information
  - --engineering
- Develop legislative support.

Discussion

While the "Smokey-the-Bear" fire prevention campaign has been undeniably effective at heightening public awareness on the danger of wildfires. the public remains largely unaware of the high economic cost of wildland fires, in terms of suppression costs and long-term resource loss. The group agreed that such awareness is essential to justify the need to increase budget allocations for fire research, fire prevention efforts, and modern suppression. Furthermore, awareness would also support the need for more effective land use planning and construction techniques called for in the prevention vision.

Staffing

Vision

Public agencies would be staffed with highly skilled professionals, who would form a balanced distribution of ages, ethnic backgrounds and gender.

Strategies

- Agencies work with universities to establish career ladders for resource professionals.
- Develop attractive salary scales.
- Focus recruitment at pre-university levels.
- Attain agency commitment to realistic staffing to meet agency mandates.

Discussion

The group expressed a strong concern over the future availability of qualified staff. Agencies need to place more emphasis on orienting young people toward careers in resource management, particularly among communities that have been traditionally underrepresented in this field.

The strategies for this vision also highlight the problems placed upon career planning and recruitment by traditional low salaries and fluctuating staff levels. The natural resource field must compete against higher paying professions as students plan their academic career. Furthermore, the vagaries of employment opportunities in the field, created by staff reductions and redistributions, makes a career with resource agencies an uncertain prospect for young people today.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Anticipated Effects of Urbanization on Fire Protection in California's Wildlands: Report of Futuring Group 2[1]

KEY TRENDS OF URBANIZATION

1. The population of the state's wildlands continues to increase rapidly.

2. The character of the wildland population is changing--more people are moving into the wildlands from urban areas; the population is becoming older; there is more ethnic diversity; the people are more active in local government affairs.

3. The general population continues to lack knowledge, awareness, and understanding of the wildland fire problem.

4. The population expects urban-type fire protection services in the wildlands but seems unwilling to pay for such services.

5. The cost of providing fire protection in the wildlands continues to increase tremendously partly because of the growing complexity of the fire problem.

6. Wildland fires are increasingly costly in terms of damages to lives, property, and natural resources.

7. Political bodies and the political process are not effective in dealing with the changing fire problem in the wildlands.

8. The fragmentation of local fire protection organizations results in decreased efficiency and increased costs of fire protection, and increased losses to lives, property, and natural resources.

9. New subdivisions and other developments in the wildlands increase the need for fire protection but do not pay their fair share of that protection.

10. Urbanization in the wildlands is decreasing the land-base of natural resources, thereby increasing the economic value of the remaining resources and placing a greater stress on their management and use.

KEY VISIONS AND ASSOCIATED STRATEGIES

Public Awareness

Residents would be more aware of wildland fire problems and more responsible for their own fire protection.

Strategies

- Inform people of the limitations of fire protection services and their responsibilities for protecting themselves.

- Develop more effective methods of public education, partly by assessing past methods (both successes and failures).

- Require that real estate disclosures include a description of the wildland fire problem.

- Define the wildland fire problem more clearly.

- Increase the amount of public education by using all fire protection personnel.

[1]Prepared at the Symposium on Wildland Fire 2000. April 27-30, 1987, South Lake Tahoe. California.

Fire Management Organizations

Fire protection organizations would consolidate greatly and cooperation would improve among the remaining organizations.

Strategies

- Determine the cost-effectiveness of the existing system of fire protection organizations and develop more cost-effective alternatives.

- Develop methods, including enabling legislation, to encourage implementation of the preferred alternatives.

- Educate the public and politicians in the preferred alternatives and the need to implement them.

Management Ethic

Management ethic of stewardship for all privately owned wildlands would be accepted by the government and the public.

Strategies

- Define the preferred stewardship ethic.

- Include courses in resource management in the college curriculum for land-use planners.

- Accelerate public education in the protection and management of natural resources.

- Assign a state or federally funded staff position to appropriate counties to be responsible for technical assistance in the protection and management of natural resources.

Costs of Fire Protection

Mechanisms would exist to collect the true costs of fire protection from the individuals and organizations creating the need for and receiving the protection services.

Strategies

- Identify the true costs of fire protection and assign them to the appropriate individuals and organizations.

- Determine how best to inform the appropriate individuals and organizations of their assessments for fire protection in a timely manner.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Fire Organizations and Administration: Report of Futuring Group 3[1]

Futuring Group 3 identified 12 trends that determine the way fire administrators must plan and budget for efficient wildland/urban fire protection organizations in the future. Five key visions and associated strategies were also identified.

IDENTIFIED TRENDS

1. Operating with reduced budgets, requiring better cost accountability.

2. More public and political involvement in the management process.

3. More interagency cooperation and consolidation.

4. Inability to organize and manage the large amount of available data.

5. Less political support for programs.

6. Difficulty in recruiting and retaining qualified and talented people.

7. An increase in the diversity of the work force (Affirmative Action).

8. Technological advances in equipment that requires high quality training for our personnel.

9. A changing society, from production-oriented to service-oriented.

10. Continued urbanization of the wildlands.

11. Changes in agency missions (expansion).

12. Influx of more trained and educated professional management specialists into wildland fire management.

KEY VISIONS AND ASSOCIATED STRATEGIES

Job Selection Training and Promotion

Job selection, training, promotion, and career opportunities have moved beyond affirmative action strategy to the point where all such actions are based solely on qualifications and abilities.

Strategies

- Continue and increase emphasis on affirmative action by all agencies and accountability to insure that desired results are achieved.

- Conduct outreach recruitment in the areas where the targeted populations live.

- Start training in the lower levels of education.

Values at Risk

Continued urbanization of wildlands would greatly increase the values at risk in wildland fire management. The mission of all wildland fire agencies would include structural protection, emergency medical service, and natural resource management.

Strategy

- Adjust agency operating policies to present demands of emergency and resource management.

Operating Budgets

While operating budgets would not increase substantially, they would at least be adjusted

[1]Prepared at the Symposium on Wildland Fire 2000, April 27-30. 1987, South Lake Tahoe. California.

for inflation. Consolidations, cooperation, and co-locations would significantly reduce duplicate efforts, thus allowing modest program expansion. Cost accountability would encourage the use of good program budgeting and implementation of productivity measurement standards.

Strategies

- Consolidate, co-locate, and increase cooperation where appropriate and where needed.

- Establish measurable standards of productivity.

- Develop good cost accounting systems and procedures.

Fire Service Coordination

"One voice" would represent all fire services (NWCG, N.F.A., etc. unified) and recognize the national fire problems. Together they would have the support of the state legislators and the U.S. Congress to reduce national fire losses.

Strategies

- Establish and maintain strong liaison between national wildland fire groups and municipal and volunteer organizations.

- See to it that the unified group actively lobbies for improved service to the public.

Technical Advances and Productivity

Technological advances in equipment and apparatus and highly trained personnel would allow us to be very effective with fewer personnel.

Strategy

- Keep abreast of current technology by sharing among agencies.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Using High Technology in Fire Management: Report of Futuring Group 4[1]

TRENDS IDENTIFIED

Use of Artificial Intelligence (AI) Techniques

1. Using knowledge-based (expert) systems as aids in decision making for all aspects of fire business.

2. Using AI as a programming paradigm.

3. Increasing emphasis on more automated data analysis and reduction.

User Problems in Technology Implementation

4. A growing gap between research and "on the ground" users.

5. Expense of "high tech" causing lethargy in implementation.

6. Time lag in technology transfer.

7. The "vision" of research differs from the "vision" of users.

8. Sophisticated hardware and software creating a hardware gap as well as a user learning gap.

9. User friendliness of software increasing.

10. Costs of systems and software decreasing rapidly.

11. Easily available and spatially registered natural resource data (Geographic Information Systems) are increasing.

12. Graphics and image data are simplifying computer output.

13. Implementation of "high tech" is putting 21st century technology into 19th century management structure.

14. Using computer prediction as a tool, not as an answer. The user needs to know where the answers come from for effective use.

15. Moving data anywhere, anytime. Information is readily available.

16. The public wanting to know what has happened and what is predicted in prescribed and wild fires.

17. Dissimilar tools (software, hardware) makes coordination among agencies and even within agencies difficult. Need for common vocabulary, syntax, and grammar in the knowledge representation.

VISIONS AND STRATEGIES

The above trends led to the following Visions and Strategies for implementation.

Availability of Information

Fire managers would casually rely on their Decoder Watches to facilitate decision making regarding Initial Attack, Escaped, and Prescribed fires. Information available would include fire behavior, climatology, fire effects, resource objectives, and expected cost/benefit analysis. This information would also be available on sophisticated graphics displays.

[1]Prepared at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

Strategies

- Generate data bases and programs

- Finish FFAST. a real-time infrared fire location and monitoring system.

- Specify a delivery system and display system.

- "Buy it" (commit to the system).

- "Sell it" (transfer the technology).

Understanding by Users

Users would understand the assumptions, reasoning, strengths, and weaknesses of the programs/systems they use. They would integrate the results of the systems with their own skills and judgment.

Strategies

- Develop self-explaining layered programs. (A program in which the answer supplied by the user at one step automatically directs him to the next step. Instructions are supplied at each step).

- Develop proper training methods for delivery of products generated in this format.

- Develop a process for knowledge acquisition from preretirement personnel (debriefing).

Portability of Data Base

Knowledge would be portable from one system to another, by adoption of a common rule syntax-knowledge representation. An agreed-upon Knowledge base shell (a generally proprietary program that utilizes the knowledge of subject matter experts) would be characterized by portability (runs on different hardware easily), expandability (easily modified and added to), and public domain (very low cost and easy availability).

Strategy

- Form an interested interagency, international, and university group, supported by committed top level decision makers, to quickly select a knowledge representation.

Geographic Information Systems

1. All Government agencies and the public would have access to current natural and human resource data, which are spatially registered and integrated. These data would be readily available to all locations at resolutions appropriate for all levels of wildland decision making and research.

Strategies

- Make a long-term commitment to delivery and upkeep of a natural resources database (see preceding vision as well).

- Discourage turf disputes--deal with the land and its characteristics.

2. Research, development, and users would be closely coupled in the technology transfer process. Technology transfer would be integral to the research planning process, and would take into account the political, economic, and operational constraints on the user.

Strategies

- Technology transfer an integral and funded part of the research process. Development is recognized as necessary.

- Encouraged users to seek research.

- Effective technology transfer should be recognized as a researchable problem.

CONCLUDING REMARKS

Many of the strategies require funding. Of greater importance, however, is a long-term serious commitment throughout the user community to foster, accept, and take advantage of new technology. Funding without this support, or commitment without the funding, would not work.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Tactics and Equipment: Report of Futuring Group 5[1]

Futuring Group 5 identified nine trends and their implications to the wildland/urban interface fire problem, with specific emphasis on fire suppression equipment and tactics.

KEY TRENDS

1. Increased area and exposure of "urban/wildland interface."

2. Greatly increased number of expected fires.

3. Increased requirements for suppression requirements with fewer personnel and less equipment ("doing more with less").

4. Greater accountability for actions and decisions.

5. Improved predictive skills (fire behavior, suppression and tactical effectiveness).

6. Increased capabilities through technological advances.

7. More sophisticated equipment.

8. Increased sharing of both firefighting and nonfirefighting resources and information.

9. Tactics increasingly influenced by regulation.

VISIONS AND STRATEGIES

Considering these trends and their implications to fire management agencies responsible for the protection of wildland/urban interface communities and developments, several vision statements were developed which encapsulate current shortcomings and needs to effectively cope with forthcoming wildland/urban interface problems.

Minimizing Fire Risks

Wildland/urban interface communities, structures, and landscapes would be carefully constructed to minimize fire risks. Homeowners, local governments, and private sector interests would acknowledge and accept their responsibilities for maintaining safe environments. Fire services will be trained, equipped, and funded to adequately protect lives, property, and resources to sustain the living and recreational environments that have drawn people into urban/wildland interface areas.

Strategies

- Determine minimum national standards for cross-training.

- Devise local codes, legislation for development.

- Establish incentives structures involving different insurance rates, taxes, etc.

- Inform public of problems by using mass media.

- Provide multiple use equipment, for structural and wildland fires.

Sharing Resources

Efficiencies would be gained through fully shared resources:

- All suppression resources (both urban and wildland) would be available and will be allocated/deployed through a coordinated

[1]Prepared at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe. California.

system (coop agencies, etc. in place) to any national or international incident.

- Equipment, personnel, information, and systems are shared extensively with non-fire functions to allow multi-functional cost sharing and enhanced over-all benefits to the public (cross functional use of fire weather, etc.)

Strategies

- Consolidate jurisdictions.

- Fully implement an incident command system (ICS).

- Establish additional new interagency dispatch centers.

- Develop long-range weather forecasts for resource allocation.

- Continue to establish interagency communications systems.

Improving Suppression Capabilities

Fire suppression capabilities will be improved through the adoption/implementation of state-of-the-art technology. Technologies in computer electronics will reduce suppression/dispatch times by aiding the firefighters with onboard computer access to behavior projections, locational information, etc. Advent of more efficient chemicals and foams compatible with all urban/wildland fire suppression equipment will reduce resource losses.

Strategies

- Develop an improved system for technology transfer (both national and international).

- Support continued development of new technology for fire suppression.

- Implement training for use of new technology.

- Expand existing technology.

- Develop guidelines for effective use of technology.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

The Role of Prescribed Fire: Report of Futuring Group 6[1]

Fire is a natural element of the wildland ecosystem. Total exclusion of fire from the wildland creates an unnatural condition: an excessive buildup of decadent and overmature vegetation.

KEY TRENDS

1. Increasing conflict between the definition of "unwanted" and "wanted" fire. Belief that all fire is bad and unwanted is giving way slowly to the understanding that fire is necessary and natural.

2. Only a very small percentage of unwanted fires occurring under unusual or extreme conditions are causing the majority of losses and damages.

3. Fire suppression costs are escalating to exorbitant and unacceptable levels.

4. Fire management philosophies are recognizing "cost versus loss" evaluations in strategy and command decisionmaking.

5. Need for effective prescribed burning to minimize the threat of major destructive conflagrations.

6. The perception of all wildfire as destructive is giving way to a unified view of positive and negative impacts and benefits.

7. Analyzing the benefit/cost ratio of prescribed fire and wildfire is leading to a significant increase in prescribed burning.

8. Increase in the number of wildfires being managed for their fire related benefits and in the total acreage burned.

9. Decrease in fire size and intensity of destructive conflagrations, in catastrophic fire dollar damages, and in ultimate net suppression costs.

KEY VISIONS AND ASSOCIATED STRATEGIES

Public Influence

Public influence in encouraging prescribed fire programs would intensify.

Strategies are these:

- The National Wildfire Coordinating Council (NWCG) to establish a public information and education program based on the positive benefits of prescribed burning.

- Environmental, taxpayer, and special interest groups to support prescribed burning due to its essential role in the natural environment and the necessity to reduce suppression costs.
- A new and aggressive public relations campaign to achieve public understanding and acceptance of fire's positive role.

- Fire agencies to contract for "Madison Avenue" type public information campaigns. Caricature image of the "Friendly Flame."

- Widespread use of prescribed burning and the treatment of certain wildfires as prescribed burns.

Air Quality

Prescribed fire management would be an effective method of minimizing critical periods of air quality degradation by controlled timing and pollutant dispersion management.

[1]Prepared at the Symposium on Wildland Fire 2000, April 27-30. 1987, South Lake Tahoe, California.

Strategies are these:

- Research to identify types, amounts, and chemical species of airborne pollutants and their specific impacts on air quality.

- Fire management agencies to cooperate and coordinate in achieving effective technology transfer.

- Fire management agencies to play an active and crucial role in lobbying for realistic smoke management regulation.

- Train all users of prescribed fire in smoke management techniques through NWCG. Develop a consolidated and interagency Prescribed Fire Management Handbook.

Economics

Economics would play an increased role in evaluating fire management policies. Costs, values, and potential losses would be considered in balance to determine prescribed fire management versus fire suppression policies.

Strategies are these:

- Calibrate more accurately the costs of fire suppression and measure them against potential losses.

- Use prescription management as an option to full suppression (i.e., allow the fire to progress to natural containment points as if the same area were burned under a planned prescription).

- Develop standardized cost/benefit/loss elements for prescribed fire and wildfire.

Training and Certification

There would be increased scrutiny, both internally in the fire agencies and from the public. Accountability for fire management policy and strategies would increase.

Strategies are these:

- Develop prescribed fire qualification and certification standards for fire personnel.

- Establish prescribed fire practitioners both in agencies and in the private sector.

- Increase experience of prescribed fire management professionals by training, qualification, and certification programs. Training will be available to both public and private sector personnel.

- NWCG to play an integral role in fostering coordinated training and the development of the Prescribed Fire Management Handbook.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Beneficial Use of Fire: Report of Futuring Group 7[1]

Futuring Group 7 identified nine trends that frame the way prescribed fire will be used in the future. The group identified three key visions and associated strategies.

IDENTIFIED TRENDS

1. Continuing need for correlation of fire behavior with fire effects.

2. More information becoming available on the effect of fire on specific ecosystems.

3. The public at large giving less support to the exploitive use of natural resources.

4. Wildland owners and managers conducting prescribed burns with or without research needed to help them meet their objectives.

5. Increasing interest by both the public and land managers in the utilization of fire and fire effects in land management.

6. Public perceiving fire more favorably, as an alternative to other methods of land management.

7. Decreasing reliance on federal agencies to research fire effects, and an increasing dependence on research by universities and consultants.

8. Litigation process requires more data on fire effects.

9. Greater public understanding and interest in the environment is resulting in increased public involvement in wildland management.

[1]Prepared at the Symposium on Wildland Fire 2000, April 27-30. 1987, South Lake Tahoe, California.

KEY VISIONS AND ASSOCIATED STRATEGIES

Scientific Fire Effects Information

Scientific fire effects information would be available to support or justify land management practices involving the use of fire. Questions concerning fire effects may be used in the the litigation process.

Strategies

- Increase funding by lobbying key people such as legislators.

- Assess legal response of land managers for managing fire effects (laws may provide justification for funding collection of data).

Fire Effects Related to Ecosystems

Fire effects research would be expanded and organized around unifying integrated ecosystem level concepts and would be conducted by interdisciplinary teams of agency, academic, and private researchers and the technology transferred to land managers.

Strategies

- Increase money invested in research.

- Define research needs, skills and relevant geographical areas.

- Develop a public education program.

Fire Effects Information as a Guide to Managers

Specific fire effects/fire regime research results would be employed by land managers to guide prescribed fire management for natural ecosystems and multiple use wildlands.

Automatic data processing methods would be an integral part of the process.

Strategies

- Continue and expand work toward fire effects data base design and development.

- Use more and better technology transfer methods.

- Increase the level of fire effects research funding.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Fire Occurrence and Behavior Analysis: Report of Futuring Group 8[1]

Futuring Group 8 represented a combination of two original topics--Fire Behavior/Fuel and Fire Danger Rating--which was subsequently renamed by its members. For purposes of clarification, some simple definitions of terms, as taken from Merrill and Alexander (In press) are deemed in order:

Fire occurrence - The number of fires started in a given area over a given period of time.

fire behavior - The manner in which fuel ignites, flame develops, and fire spreads and exhibits other related phenomena as determined by the interaction of fuels, weather, and topography.

The term "fire danger rating" is used as a management system to evaluate the various factors influencing fire potential, chiefly for the purposes of determining fire protection needs.

IDENTIFIED TRENDS

1. Continuing need for better and better "fire intelligence systems" (Barrows 1969) in fire suppression and fire use programs.

2. Adoption and increasing use of Geographic Information Systems (GIS) in fire management (e.g., Kessell and others 1984).

3. Steadily increasing demand for three-dimensional fire growth modeling (e.g., Kourtz 1984) for use in presuppression planning, including training, and daily operations.

4. More and greater expectations of fire managers due to external and internal pressures (e.g., cost-effectiveness, urban/wildland interface problems).

5. Increased weather data gathering activity (e.g., remote automatic weather station or RAWS networks, lightning locator systems, precipitation radar, satellite imagery).

6. Greater demands on the existing systems used to evaluate fire danger and predict fire occurrence/behavior (i.e., they are being applied to fire problems/opportunities which exceed their original purpose or capability or both).

7. Significant improvements in electronic communications.

8. Gradual acceptance of centralized fire control centers.

9. Skill level of some fire management personnel being surpassed by the state of knowledge and new technology.

10. Widespread misunderstanding of the proper application(s) of the present analytical systems available for fire occurrence and behavior.

11. Growing interest in more robust schemes for predicting human-caused and lightning-caused fire loads.

12. Tendency towards greater international cooperation in fire research (e.g., Albini and Stocks 1986).

13. Necessity for designing systems to address all levels of fire management activities (Rothermel In press).

14. Continuing demand for "longer-range" weather forecasts.

[1]Prepared at the Symposium on Wildland Fire 2000, April 27-30. 1987, South Lake Tahoe, California.

15. Increased interest by fire-prone countries in the use of the various other national systems of fire danger rating developed in Canada, Australia, and the United States (e.g., Valentine 1978, Peet 1980, Van Wilgen 1984).

KEY VISIONS AND ASSOCIATED STRATEGIES

Basic Models of Physical Fire Phenomena

Comprehensive fire occurrence and behavior models would take into account nonuniformities in fuels, topography, and weather.

Strategies

- Conduct problem analyses to identify knowledge gaps.

- Fund basic fire research and model development to address the needs identified above.

Practical Application of Models in Fire Management

An internationally accepted family of fire occurrence and behavior systems would be available to serve the needs of fire management at all levels within the organization, from planning to operations for both wildfire and prescribed fire.

Strategies

- Form an international working group to coordinate system development.

- Determine the needs of fire management with respect to wildfire and prescribed fire applications.

- Design a family of systems for predicting fire occurrence and behavior.

- Build and test these systems.

Centralized Fire Control Operations

Centralized fire command centers would use data from satellite transmissions, advanced weather gathering systems, and other state-of-the-art technology. Integrated systems would display last known fire perimeter and intensity as well as predicted fire growth on a near real-time basis.

Strategies

- Conduct an in-depth feasibility study with respect to engineering and development requirements, options/alternatives, etc.

- Follow the course of action recommended above.

Role of Geographic Information Systems (GIS)

A computerized data base on fuels, terrain, etc., would be available for use with weather models (e.g.. wind flow over complex terrain) and forecasts for predicting the occurrence and behavior of potential or going fire situations. The predictions would include not only the probabilistic (rather than deterministic) outcomes of conventional parameters (e.g., probability of ignition, rate of spread, intensity) but other important considerations (e.g., likely location and timing of fire whirl development, blowup potential). Predictions from fire growth models can be updated using near real-time surveillance of actual fire perimeter.

Strategies

- Survey the construction, content, and use of GIS.

- Explore the feasibility of using GIS in a fire intelligence system.

- Supply fire research input to GIS plans.

- Incorporate GIS into fire intelligence systems.

Training of Fire Management Personnel

Fire managers would understand and use the appropriate analytical systems for predicting fire occurrence and behavior through training courses and field application, interpretation, and evaluation of results.

Strategies

- Determine the specific training needs of fire managers.

- Develop and conduct a series of mododularized training courses.

- Ensure that quality control for monitoring user's performance in using the systems takes place and is maintained.

REFERENCES

Albini, F. A.; Stocks. B. J. 1986. Predicted and observed rates of spread of crown fires in immature jack pine. Combustion Science and Technology 48: 65-76.

Barrows, J. S. 1969. Intelligence systems for forest fire control. In: Proceedings Sixth World Forestry Congress; 1966 June 6-18; Madrid, Spain. Madrid. Spain: Spanish Ministry of Agriculture: 1934-1940.

Kessell, S. R.; Good. R. B.; Hopkins. A.J.M. 1984. Implementation of two new resource management systems in Australia. Environmental Management 8: 251-270.

Kourtz, P. Decision-making for centralized forest fire management. 1984. Forestry Chronicle 60: 320-327.

Merrill, D. F.; Alexander, M. E., eds. [In press]. Glossary of forest fire management terms. Fourth edition. Publication NRCC No. 26516. Ottawa. ON: National Research Council of Canada. Canadian Committee on Forest Fire Management.

Peet, G. B. 1980. Forest fire management planning, Kenya: Fire danger rating for forest areas. FAO Document FO:DP/KEN/74/024, Technical Report 1. Rome, Italy: Food and Agriculture Organization of the United Nations. 93 p.

Rothermel, R. C. [In press]. Fire behavior research: where do we go from here? In: Postprint Volume Ninth Conf. on Fire and Forest Meteorology; 1987 April 21-24; San Diego, CA. Boston, MA: American Meteorological Society.

Valentine, J. M. 1978. Fire danger rating in New Zealand: review and evaluation. Forest Establishment Report No. 123. Rotorua, NZ: New Zealand Forest Service, Forest Research Institute. 53 p. Unpublished.

Van Wilgen, B. W. 1984. Adaptation of the United States Fire Danger Rating System to fynbos conditions. Part I. A fuel model for fire danger rating in the fynbos biome. South African Forestry Journal 129: 61-65.

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

International Issues: Report of Futuring Group 9[1]

The wildland fire scenario outside North American is characterized by increasing amount and severity of wildfires worldwide. In Europe, most of the Mediterranean countries suffer devastating forest fires, despite fire management efforts. Examples of the wildland fire theater within the developing countries and the tropical world have been given at this Symposium on Wildland Fire 2000. Most of the wildfires in Latin America, Africa and Asia, however, are not monitored and remain unreported. Only a few spectacular wildfires are noticed by the world media and public. The 1982-83 rain forest wildfires in Borneo (East Kalimantan, Indonesia) were reported because of growing international concern in the decrease of the tropical forest land base. The same refers to the 1985 fires on the Galapagos islands, which threatened one of the world's most unique ecosystem reserves. The 1987 forest fires in China were observed because they caused more than 200 deaths and wiped out whole towns and villages.

On the other hand, there is a growing interest in the global impact of forest fires and biomass burning and its potential contribution to atmospheric changes.

The futuring session on "International Issues" therefore focused its visions on global aspects of wildfire impact and international cooperation. Special attention was given to developing countries and the tropics/subtropics.

KEY TRENDS

The 13 key trends elaborated can be categorized into three groups highlighting the background scenario, the ecological impact of wildfires, and the relevant international approaches towards solving this problem. A brief background explanation is added to each key trend.

Socioeconomic Trends Affecting Forest Resources

1. Growth of the world's population to 6.2 billion by the year 2000. Countries facing the most serious growth are developing countries and mainly those within the tropics.

2. Energy crisis limiting economic growth and standard of living in most developing countries.

3. The aforementioned development leading to political destabilization and affecting sensible decisions in fire management.

4. Decreasing world forest land base. Tropical forest resources increasingly used and wasted. Large-scale conversion of forest land to other land-use, leading to degradation in some cases.

5. Lack of coordination between government agencies. Policies don't match implementation.

Environmental Impact of Wildfires

6. Changing fire regimes. The combination of social, economic and physical impacts making most forest and wildlands more fire prone.

7. Increase in wildland fires. Throughout the world wildland fires having greater impacts on forest resources, people and property.

8. Changing species composition. Vegetation types regularly affected by wildfires being dominated/invaded by fire-tolerant/resistant species.

9. Increasing climate variability from human-caused pollution, due to interconnectedness of ecosystem responses.

[1]Prepared at the Symposium on Wildland Fire 2000, April 27-30, 1987, South Lake Tahoe, California.

Implications on International Concepts

10. Increasing need for fire education in resource management programs.

11. Exchanging wildland-fire related data from other countries will be gathered, results will be applied to each other.

12. Greater communication and cooperation fostering international solutions to world problems.

13. Growing nongovernment interest groups exerting more influence on decisionmaking processes.

VISIONS AND STRATEGIES

The three visions elaborated describe an image of a preferred future that is attainable. It serves as a guide to interim strategies, which are briefly described.

Ecosystem-Use and Response

Relationships between use of the ecosystem and ecosystem response, particularly tropical ecosystems, would be understood. These ecosystems would be managed to harmonize the forest and needs of rural populations.

Strategies

- Monitor and evaluated trends.
- Develop scientific and technical base between ecosystem-use and response.
- Develop a strategy to integrate land-use and population.
- Develop public awareness.
- Provide local incentives and adequate funding for local people to develop sound conservation practices and to start-up and sustain multiple-use forestry, agroforestry or social forestry systems.
- Monitor and evaluate effectiveness strategies.

Fire Regimes and Fire Management

Fire regimes would be managed in priority zones to ensure conservation of species with minimum impacts on resources.

Strategies

- Identify, define and actualize world-wide fire regimes.
- Identify sensitive areas that need fire protection.
- Compile and publish state of existing knowledge on fire problems in tropical forests.
- Develop fire management strategies.
- Include mitigation measures in forest planning to reduce fire losses.
- Set resource management objectives and priority zones.
- Develop public involvement awareness programs compatible with regional cultures.
- Identify undesirable exotic species that should not be introduced into the ecosystem.
- Organized international symposia on fire regimes, mainly on tropical biota, also on temperate zones and other less understood ecosystems.

Forest-Atmosphere Interactions

The extent and processes of forest-atmosphere interactions would be clearly understood. This knowledge would be used in land management strategies.

Strategies

- Monitor worldwide effects of pollution on ecosystems (specifically carbon cycle).
- Increase international cooperation and coordination.
- Identify sources of pollution. Prioritize control and restrict pollution sources.

- Promote reforestation in tropical areas.

- Integrate fire management and land management planning.

- Increase research funding to create a scientific base for implementing strategies.

CONCLUDING REMARKS

The world is facing growing and complex environmental problems, such as forest damage in Europe, deterioration of lakes in Scandinavia and North America, climatic impact of deforestation in the tropics, desertification, and a growing level of tropospheric oxidants. There are increasing demands for reliable information and for action. The role of wildfires and biomass burning as well as other burning processes in global ecological interactions are currently not yet understood completely. This is the challenge to the international community of wildland fire scientists and managers. It is also a challenge to an International Geosphere-Biosphere Program whenever launched in the near future.

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This "futuring" symposium addressed the possible, preferred, and probable status of wildland fire management and research in the year 2000 and beyond. Papers cover the fire protection needs of the public, management response to these perceived needs, and the research and education required to meet these needs. Also covered in a separate section are the interactions between forest user, manager, and researcher, as well as international issues. Nine papers, developed by the futuring process and presented at the symposium examine key trends, define preferred "visions" of fire management in the year 2000, and describe strategies to achieve these visions. One paper describes how the Incident Command System (ICS), which is popular among fire service agencies, was used to organize and conduct the symposium.

Retrieval Terms: artificial intelligence, expert systems, fire effects, fire management, futuring, prescribed burning