PREDICTING FIRE BEHAVIOR IN THE WILDLAND-URBAN INTERFACE

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ABSTRACT

Fire exclusion in wildlands during the last century has caused the excessive accumulation of fuels that has resulted in catastrophic fires. In spite of devastating losses from fire, human development continues to increase in the wildland-urban interface. Additional houses and other structures are being built each year in areas that are prone to high-intensity wildfires, with increasing threats to life and property.

The term "risk" is sometimes considered synonymous with "hazard." However, risk has the additional implication of the chance of a particular event actually occurring. By determining areas of high risk from fire, managers (including planners and policy makers) can establish priorities in reducing adjacent wildland fire hazards. Evaluation of hazards can be accomplished by utilizing Geographic Information Systems (GIS) to map high hazard areas where wildland and urban land uses meet. A GIS landscape database containing utilities, structures, access, water, and adjacent wildland fuels and vegetation can be used to develop fire cost plus loss scenarios. Fire behavior models, such as FARSITE, can simulate fire activity given specified parameters.

Besides helping managers establish plans for reducing fire risk, these tools can also be used to help educate the public. GIS mapping will enable managers to illustrate areas that are at high risk of fire and to speculate on the probable consequences of taking no suppression action. Prudent use of prescribed fire can reduce property loss, minimize costs, and potentially save lives.

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INTRODUCTION

Fire behavior corresponds to vegetation, topography, and climate. Processes such as drought, pests, and wildfires are normal components of forest environments (McLean 1993). Each year thousands of acres of wildlands are burned by fire. Many natural resource values are consumed including timber, forage, wildlife browse, wildlife, natural aesthetics, and recreational lands. Water quality is threatened. Structures, vehicles, communication lines, powerlines, and other human developments are also affected by wildfires (State of Utah 1978). The current conditions in many forests of the Inland West allow the normal wildfire situations to become catastrophic events (Sampson et al. 1994). The prevalence of large and severe wildfires in the Inland West since the 1970's suggests that attempts to eliminate fire have simply led to a pattern of large severe fires burning in heavy fuels. During 1988, $145 million was spent to suppress wildfires in the Yellowstone area to protect homes and multimillion dollar resorts. During 1991 the Oakland fire consumed 3,403 homes, burned 1600 acres (670 hectares), incurred $1.5 billion in property damage, and took 25 human lives. During 1993, southern California lost 1,000 structures and 207,000 acres (83,800 hectares) for total damages of $2 billion and took $22 million to control.

By developing fire risk models and determining high risk areas, managers can set priorities and develop mitigating measures to reduce hazards. By using fire behavior models, managers may also visualize how a fire may react in a given environment with set parameters. These measures could be used as tools in educating the public as well as local, state, and federal agencies. Managers could show areas where urban planning and building codes are inadequate to assure public safety.

Definitions

The point at which flammable natural vegetation meets human development is the wildland-urban interface. It is this interface that has created the current fire protection challenge (Bailey 1991). Interface areas can range from deserts where a flush of flammable growth follows a rain to undeveloped park land inside a major metropolitan area, such as a wildlife preserve. The interface may also be called the wildland-urban intermix as interface connotates a boundary where intermix is the intermingling or mixing of structures in wildland areas. Almost every part of the nation has a wildland-urban interface problem. Almost every western city has been affected by wildland fires.

There are three general types of interface areas (Davis 1989):

- Classic interface is an area of urban sprawl where city boundaries and suburbs press against wildland vegetation. Fires starting in the adjacent wildland areas can propagate a massive flame front and put homes at risk. By far the

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greatest number of people live in (and are moving into) the classic interface.

- Mixed interface is an area where homes and other structures are intermixed with wildland vegetation. Typical in this setting are summer homes, recreation homes, ranches, and farms.
- Occluded (or isolated) interface is where islands of wildland vegetation occur inside a metropolitan area. Examples include a wildlife refuge or an undeveloped park.

Some regions could have combinations of these types. This is particularly true where cities are pressing into the wildland and people are building further into the wildland.

The term risk is sometimes taken as synonymous with hazard but risk has the additional implication of the chance of a particular hazard actually occurring. Thus, hazard may be defined as a threat to humans and their welfare, and risk as the probability of hazard occurrence. So disaster may be seen as the realization of hazard. Hazards may be considered in three categories: 1) hazards to people—death, injury, disease, stress; 2) hazards to goods—property damage, economic loss; 3) hazards to environment—loss to flora and fauna, pollution, and amenities (Smith 1992).

Concerning fire, risk is a wildfire causative agent. Examples of causative agents are: lightning, chainsaws, and campfires. Hazard is a rating assigned a fuel complex (defined by kind, arrangement, volume, condition, and location) that reflects its susceptibility to ignition, the wildfire behavior and severity it would support, and/or the suppression difficulty it represents (Walstad et al. 1990). O'Laughlin et al. (1993) define risk as the probability of an undesirable event occurring within a specified period of time.

Natural hazards can be defined as threats to human resources resulting from extreme events in nature (generally floods, tropical cyclones, earthquakes, and drought). Extreme events themselves are not hazards but often produce hazards when their impact on human activities is undesirable (Beebe and Omi 1993).

The question of risk is at the center of the options facing society in the Inland Western forests. Any management action, including the option of taking no action at all, has certain costs and uncertain outcomes. Inaction in the face of current forest conditions will likely prove to be the most costly and environmentally destructive option (Sampson et al. 1994).

The Problem

There were significant population shifts from urban to rural areas during the 1970's and early 1980's. The move to the interface continues, but at a lower rate. An analysis of the U.S. demographic data suggests a dramatic increase in the number of persons choosing to live near forest environments. The U.S. Forest Service reported a population gain of 23.4% between 1970 and 1980 in the rural counties surrounding the nation's forests, more than twice the 11.4% population gain for the nation as a whole (U.S. Fire Administration, 1992). In Kootenai County, Idaho from 1990–1995 there has been a population increase of 31.4%, with Bonner County, Idaho at 24.3%, and Idaho as a whole at 15.5%, whereas the nation's population increased 5.6% (Hansen 1996).

There are many reasons for moving to the wildland-urban interface. Most people have moved for amenity values or for economic reasons unrelated to traditional rural land uses, such as forestry or farming. Some people want a pace of life that is quieter, where the air is cleaner, where there is less violence and crowding, and where these factors combine to provide a good place to raise a family. Other reasons for moving include improved transportation and communication. More roads are being built and dirt roads are being improved and paved. Also, with the coming of the information age, computers with modems allow people to conduct business from home by telecommuting to their work. People moving to the wildland-urban interface give little thought to the wildfire hazard and bring with them their expectations for the continuation of urban emergency services (USDA and USDI 1995).

There are many barriers in addressing fire management problems related to the wildland-urban interface. These problems include legal mandates, zoning regulations, fire and building codes, basic fire protection infrastructure, insurance/fire protection grading and rating systems, environmental concerns, and agency fire protection agreements. Political, social, and psychological factors further complicate the problems. Leadership and cooperation are essential (USDA and USDI 1995).

Fire in the wildland-urban interface is not a new problem. It has been a factor for more than 120 years in the U.S. The Peshtigo Fire in 1871 burned 1.2 million acres (486,000 hectares) and took 1,500 lives. Although fire in the wildland-urban interface is receiving increased attention at the local, state, and national levels, there is little information on the magnitude or significance of the problem. According to Sommers (1988), the available information is often fragmented, incomplete, and difficult to aggregate on a national scale. He also states that the data are inadequate to project trends or analyze cause and effect relationships. Irwin (1987) contends that the wildland-urban 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 simultaneously. Managers are having to deal with landscapes that are being broken into smaller tracts as people move into these areas. Sonner (1994) wrote that local communities often lack the resources to fight catastrophic fires and U.S. Forest Service firefighters and others end up doing much of the work at a cost to federal taxpayers.

Protection of life and property have become the primary objectives and all nearby structures must be guarded by additional forces, even though they may not be directly or immediately threatened. This includes the increase of both the number of firefighters

Table 1. Western Governors' Association fire management model components.

Fire control factors	Slope hazard factors	Fuel hazard factors	Weather
Access/Egress	Aspect	Building Construction	Drought Factor/Index
Bridges	Dangerous Terrain	Defensible Space	Historical Climatological Data
Pre-Attack Plan	Position on Slope	Fuel Continuity	
Building Construction	Slope	Fuel Breaks	
Resources		Fuel Loading	
Response Zones		Fuel Type/Model (within and adjacent)	
Utilities			
Water Supply			

needed and the increased training needed for both wildland and structural protection. In the Payette National Forest during 1994, the U.S. Forest Service spent $35 million protecting remote areas containing a few old ranches and scattered tracts of newer vacation and year-round homes. Officials at all levels are questioning the money being spent on fire protection for homes in the interface (Dellios 1994).

Finally, defense of structures inevitably results in greater natural resource losses. The priority of life and property defense overrides wildland protection. In the article by Scott Sonner, Assistant Agriculture Secretary James Lyons said, "In large wildfires . . . city, county and rural volunteer fire departments cannot protect every home. As a result, we must divert wildland fire suppression resources from protecting natural resources to structural fire protection." Committing available personnel to protect homes may result in not being able to control the main wildfire itself (NFPA 1989).

Fires have occurred in the northern Rockies for many centuries. Studies of fire scars and even-aged stands of old timber show a consistent pattern of fire frequency from 1600 to 1900. The last large fire in Latah County, Idaho, was the 1910 fire that burned more than three million acres in Idaho and Montana (Pyne 1982). Brown et al. (1994) found that the presettlement fire regime characteristics from areas near the Selway-Bitterroot Wilderness show the fire-return interval for ponderosa pine ranged from 7–52 years with the mean being 20 years. For Douglas-fir, the range was 17–50 with a mean of 30 years. Many of these areas have not burned in 80 to more than 100 years.

Significance of Problem

Expected occurrence, or "spatial risk," over an area can be used to provide needed information such as when and how frequently wildfires can be expected to occur in the future. Problem areas tend to have distinct, unique characteristics that lend a certain degree of predictability. Hazard analysis permits evaluation of interrelationships of topography, vegetation, and values-at-risk (Close and Wakimoto 1995).

Assessment of fire hazards is necessary to assist landowners, fire managers, and regulating organizations to minimize losses of life and property due to wildfire. Fire hazards are considered here to emphasize elements of flammability and difficulty of suppression of structures, vegetation, and other fuels in the wildland-urban interface. Without a consistent process that assesses wildland-urban interface hazard and risk, values, and loss experience, it is difficult to prescribe appropriate mitigation measures (USDA and USDI 1995).

The results of this research may enable local and regional planners to better respond to a major disaster such as fire. The planners can set priorities according to levels of risk as established by the models as well as other factors. The public would be able to see the different variables (such as vegetation, slope, aspect, elevation, and human development) and also see how a fire would affect the variables.

GIS AND FIRE BEHAVIOR MODELS

Over the last decade, geographic information systems (GIS) have emerged as tools for analyzing resource management alternatives. GIS provides the technology to analyze and model vast amounts of data for planning and decision-making (Salazar 1995). GIS technology can be used as a tool to help develop plans to mitigate the effects of fire on the population, including modeling fuel hazards, developing preburn plans, and designing fire response plans. Vegetation management plans can also be implemented (Woods 1995). GIS provides the spatial framework for studying the geographical distribution of fire risk. Creating a fire hazard index involves taking into account a wide range of factors, among which weather, fuel, and topography are the most common. The most powerful capability of GIS involves the integration of spatial information (Salas and Chuvieco 1994). GIS can be used to integrate data on past fire histories, topography, access routes, and vegetation types to determine relative hazard levels.

The Western Governors' Association (WGA) is promoting the development of a fire hazard risk model as one of the issues concerning the wildland-urban interface challenge (Table 1). The criteria in Table 1 could provide a consistent hazard assessment tool. It could be used to improve interagency and intergovernmental cooperation and coordination (WGA 1995).

Factors such as elevation, ownership boundaries, location of fire stations, response times from stations, and types of apparatus available for the types of fires expected (structure or wildfire) could be included in the WGA model. Additional variables could be added such as land use zoning and insurance rating.

Fire managers can model fire behavior by using inputs of fuel models, topography, and weather. The 13 fuel models tabulated by Rothermel and illustrated by Anderson (1982) are frequently used since they are described by fuel load and ratio of surface area to volume, size class, depth of fuel bed, and fuel moisture. Interactive ties of fire behavior modeling systems such as BEHAVE with a GIS database have produced behavior models such as FARSITE (Finney 1996) and FIRE! (Green et al. 1995).

FARSITE, or Fire Area Simulator, is a model for spatially and temporally simulating the spread and behavior of fires under conditions of heterogeneous terrain, fuels, and weather. The model requires organized information of topography, fuels, and weather. FARSITE was originally intended for management support of prescribed natural fires. The model can be useful in both planning and operational phases of fire suppression. Fire growth and behavior scenarios can be developed relatively quickly using short-term weather forecasts or long-term weather projections.

FARSITE can be used for projections for both active fire and potential fires. With active fires, FARSITE can make:

1. Short-term projections for use in preparing daily fire situation analysis;
2. Short- and long-term projections that would help with scheduling fire monitoring activities based on the projected arrival, fire behavior, or fire effects;
3. Projections using weather extremes that could help define potential fire variability and range of outcomes; and
4. Short- and long-term projections could help with assigning priorities to multiple fires.

For potential fires FARSITE can determine:

1. Effects of ignition locations, fire weather patterns, and fuel or prescribed fire treatments that could be examined for comparing fire management alternatives, and;
2. Fire spread patterns and behavior under historic weather could help define fire management zones.

DISCUSSION

While the interface problem is national in scope, solutions must be designed and implemented at the local level. Cultural factors, as well as local conditions, define a region or locality and its particular fire conditions. These factors will also determine solutions which have the best chance of reducing the potential for disastrous interface fires.

Using GIS and a fire behavior model offers several advantages in modeling fire behavior. GIS can provide maps showing spatial information illustrating high hazard areas. Fire behavior models could demonstrate how a fire could spread through an area given set parameters. These parameters could be changed to show different scenarios.

Besides fire managers, this type of analysis could be helpful to other entities and to the public. Local planners, as well as regional and state resource agencies, could use this information to prioritize high fire risk areas and initiate mitigation measures. This information could be used to influence changes to be made in building codes, subdivision ordinances, and zoning regulations. Insurance companies could use this information to encourage policy holders to reduce fire hazards on their properties by offering reduced rates. Fire departments could use this information for locating and staging of fire suppression forces and support equipment.

This information can also be used as an educational tool. County and state agencies may not be aware of these fire hazards. In using the GIS and FARSITE for demonstrations, the public could see the impact of a potential fire in their area before it happens.

The availability and accuracy of databases as well as technical support (including hardware and software) are critical in preparing these risk assessments. It is necessary to have personnel trained in both GIS technology and fire behavior to properly prepare and interpret the assessments. Databases need to be maintained and updated to insure the information is accurate and enable the managers to plan using current information.

In the meantime, a billion dollar disaster is waiting to happen somewhere.

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