FireSmart Strategies for Wildland Urban Interface Landscapes

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Abstract

Wildland Urban Interface (WUI) areas are areas where human structures are located adjacent to or within combustible wildland fuel complexes and FireSmart forest management strategies are designed to help mitigate the damage that results from fires that occur there. We describe a Decision Support System (DSS) that is being developed to enhance fire management on WUI landscapes. Our WUI DSS simulates fire ignition and spread and the potential impact of fire on structures and other values based on landscape characteristics. The model predicts the probability that designated points on the landscape will burn and can be used to evaluate alternative FireSmart management strategies such as fuel treatments proposed for designated areas.

Introduction

The term Wildland Urban Interface (WUI) is often used to refer to areas where homes or other human structures are located in or adjacent to flammable wildland fuels. Many have resulted from the migration of urban residents to forested rural areas where they establish first or second residences in response to a desire to live in natural environments. Such areas are prone to fire losses since fires that occur in wildland fuels can spread across the landscape and ignite flammable structures.

WUI areas can be found around the globe and the loss of homes and other structures the evacuation of residents in WUI areas has become all too common in recent years. WUI residents do not always recognize and/or respond to the potential risk from fire in such areas and often rely on forest fire management agencies to reduce the hazard (Winter and Fried, 2000) posed by fire on the landscape. Although forest fire management agencies are sometimes the only fire protection available in WUI areas, the staff and the techniques they use are not always well suited for protecting structures from wildland fires in WUI areas (Butler, 1974; Davis, 1990; Alberta Environment Land and Forest Service, 1999). Radeloff *et al.*, (2001) documented the significant impact of human habitation patterns on landscape level processes. Such impacts have been recognized but not studied comprehensively. They suggest, as well, that landscape scale management should be based on both ecological and sociological factors. Fire management in WUI landscapes must consider human activities and the facilities associated with them, such as roads and structures. It is necessary to integrate information related to both ecological and sociological aspects in order to develop sound fire management strategies Winter *et al.,* (2002) observed that fuel treatments in WUI landscapes are more likely to be adopted if mangers understand the factors that influence public acceptance of fuel management and if WUI residents are involved in fire hazard mitigation.

When dealing with fire management in WUI areas it is important to consider the owners' private property where homeowners make decisions. The responsibility of WUI residents for fire hazard reduction is widely accepted by the homeowners. A study conducted by Winter and Fried (2000) for example, found that the 54% of the homeowners consider wildfire protection to be either a responsibility that should equally be shared between homeowners and forest fire management agencies or (26%) primarily a responsibility of homeowners. Wildfire behaviour has been extensively studied but little research has been carried out on the way fire spreads from wildland fuels into homes and other structures (Butler, 1974; Davis, 1986). The risk that wildfires will ignite individual homes or other structures is the result of complex processes that has been tackled using a variety of approaches. Some of them focus on the fire resistance (survival rate) of structures (Wilson and Ferguson, 1986; Fried *et al.*, 1999) and others focus on rating the risk of structure ignition (Cohen, 1995).

The factors that are common to most studies and that strongly influence the spread of wildfire into structures are: 1) the existence of a defensible zone; 2) the flammability of roofing material; 3) the ignitions caused by firebrands from surrounding vegetation; and 4) the distance to the nearest neighboring structure. Fire managers that deal with WUI landscapes face many challenging tasks but sound WUI fire management planning can help reduce losses (Rice and Davis, 1991).

FireSmart Forest Management

The term FireSmart Forest Management refers to a pragmatic approach that utilizes forest management practices in a proactive and planned manner to reduce the potential for fire ignitions, to decrease the fire behaviour potential of the landscape, and to enhance the capability of fire suppression resources to contain fires (Hirsch *et al.*, 2001). The aim of this approach is to assess the impacts on fire management of any forest management activity carried out on the landscape.

FireSmart management is closely related to fuel management. Fire behaviour is influenced by fuel, weather and topography and fuel is the only element that can be altered to reduce fire potential. Fuel management entails modifying the kind, amount or distribution of the fuels through which wildfires spread and can be direct (*e.g.*, fuelbreaks) or the indirect result of other land management activities (*e.g.*, silviculture). Pyne *et al.*, (1996) classify fuel management into three major categories: fuel reduction, fuel conversion and fuel isolation. Fuel reduction activities aim to decrease wildland fuel loadings to reduce fire intensity. In this way fire suppression activities are more likely to succeed. Fuel reduction treatments, like thinning and prescribed fire, need periodic maintenance in order to retain their effectiveness. Experimental thinning/slash disposal treatments located in WUI areas decreased in surface fire behaviour parameters

(Kalabokidis and Omi, 1998). Fire severity and crown scorch were significantly lower in stands that had been subjected to some type of fuel reduction treatment compared with untreated stands (Pollet and Omi, 2002). Fuel conversion involves the substitution of fire-prone species and flammable fuel with species that have lower flammabilities and lower spread rates. According to Amiro *et al.* (2001), the rate of spread can be decreased significantly by changing pure conifer stands into mixedwood stands (50% conifers-50% deciduous). Fuel isolation aims to create wide blocks or strips of bare soil or reduced fuel loads. Such breaks can stop or slow down the spread of the fire or serve as anchor points for fire suppression activities.

FireSmart practices include the design and construction of roads in strategic locations where they can serve as fuelbreaks and harvesting and silvicultural activities that vary both in intensity and timing to both enhance timber production and alter forest fuels to mitigate potential fire losses. Both fire intensity and fire size could be reduced by means of fuel reduction treatments. According to Johnson *et al.*, (1998), commercial timber harvesting activities, mechanical treatments, prescribed burning and fuel break construction can be combined not only to reduce fire size and intensity but also to improve the structural conditions of the stand and improve forest succession.

Landscape level FireSmart strategies examples include the creation of relatively large, strategically located patches that reduce the continuity of highly flammable fuels and serve as anchor points for fire suppression, especially indirect attack. Such areas would consist of low flammability fuels, such as deciduous or mixed wood forest stands. Roads, lakes and rivers could be combined with such areas. Skid trails or roads could be placed around the perimeter of a stand to prevent fires from spreading to adjacent stands or in the case of prescribed burning, reduce the risk associated with the use of prescribed fire. In case of timber production, harvesting operations can be designed to follow natural fuel type changes, topography and hydrology to reduce the likelihood of burning contiguous forest stands. In addition, cut-blocks could be oriented with respect to the prevailing wind to minimize potential control problems at the head of a fire.

FireSmart Management in WUI landscapes

Fire managers dealing with WUI areas can implement the following types of FireSmart strategies to reduce the wildfire hazard in their areas:

1) Fuel reduction treatments such as thinning, timber harvesting or prescribed burning that lower the risk of high-intensity fires.

2) Fuel isolation strategies including the creation of fuelbreaks, greenbelts and defensible zones around the WUI areas. Such treatments primarily influence fire size by preventing wildland fires from spreading into WUI areas and to buildings.

3) Fuel conversion strategies such as the establishment of greenbelts around WUI areas and the creation of fuelbreaks which contain less flammable fuel types.

4) Creation of defensible spaces around WUI areas and between structures within WUI areas. Brush clearance, grass and overhanging branch removal are some of the mitigation strategies that can be carried out to reduce the vulnerability of buildings in the WUI areas to wildfire. Studies focusing on the width of the fire-safe space (Cohen, 2000; Gettle and Rice, 2002) have concluded that 30 feet (9.1 m) can be considered a fire-safe distance.

Close this chapter

5) Increase the fire resistance of WUI structures. The use of non-flammable construction materials for roofing and siding contributes to a reduction in the ignition hazard in WUI areas. Roofing material has been found to be significantly associated with structure ignition and home losses (Wilson and Ferguson; 1986; Davis, 1990; Foote *et al.*, 1991; Cohen, 2000).

Fire managers need to acquire and use large amounts of data to develop and evaluate different FireSmart strategies. Spatially explicit decision support systems can be used to help predict where fires are more likely to occur and how they might spread across the landscape. Fire managers have to decide the desired level of protection for the landscape and the proper means to reach it. The location and intensity of fuel treatments, (*e.g.* fuelbreaks, thinning intensity) must be evaluated in terms of fire hazard reduction effectiveness as well as landscape objectives of WUI residents and wildlife characteristics of the community and the surrounding area.
In order to resolve such decisions and evaluate strategies, fire managers need information concerning several key areas:

- Fuels: mapping and fuel classification of the existing fuels as well as a characterization of the fuel condition.
- Physiography: the basic data about the landscape including topography, water bodies, roads and transportation infrastructure.
- Weather conditions: temperature, wind velocity and relative humidity influence fire ignition and behaviour processes. Insufficient fire weather information is one of the major sources of error in fire behaviour prediction (Conard et al., 2001).
- Values at risk: the location of communities, cottages and homes as well as building type, access routes and level of occupancy.
- Fire history: information related to wildland fire occurrence, fire prevention activities and the fire suppression effectiveness are needed to characterize the fire regime.
- Fire spread: an ability to model fire behaviour under specified conditions and scenarios and project it into the future is essential for evaluating fire management alternatives.

WUI Decision Support System

We are developing a WUI Decision Support System that is designed to help fires managers resolve wildland urban interface fire management problems. It is a spatially explicit computed-based model of a WUI landscape in which simulated fires are prevented, ignited, spread and fought in fuel complexes that can be manipulated in efforts to achieve the desired levels of fire activity. Our WUI Decision Support System is structured as follows:

Current forest landscape: we begin with a digital map of the landscape for which FireSmart management strategies are to be developed and evaluated. The digital map must contain both forested and WUI areas. Our objective is to develop a model or framework that can be applied to any WUI landscape rather than to develop a strategy for a specific area. The basic landscape information that is needed is:

- Fuel type: fuel is one of the basic factors that influences wildfire potential. The fuel types present on the landscape are one of the model inputs. Special attention to the scale and resolution is needed as we are dealing with WUI areas with heterogeneous fuel with a great variety of structural as well as vegetation conditions (Radke, 1995). Structures like roads and railways; and geographic features such as lakes and rivers are included.

- Values at risk: locations of communities, isolated houses and cottages or other physical structures and any natural, industrial, agricultural or recreational facilities as well as their attributes.
- Weather: historical weather records.
- Fire history: fire report data containing fire location coordinates, size, weather conditions and area burned.

Fire Occurrence: we simulate the occurrence of fires on the landscape. Fire ignition rates are based on the historical number of fires that have occurred on the landscape. Fire ignition locations are based on the historical geographical locations of fires and the current fuel types. Two ignition patterns are distinguished: human-caused fires and lightning-caused fires.

Initial Attack: this module examines the effectiveness of the existing suppression activities in the landscape. Fire statistics indicate that most of the area burned is produced by a small number of fires that escape initial attack and develop into large fires. Historical fire data is used to estimate the number of fires that will escape initial attack each year. The number of escaped fires or percentage of fires that have escaped initial attack describes the level of protection on the landscape, *i.e*., the fraction of fires that are controlled by the fire management organization.

Fire Spread: we use the *WILDFIRE* spread model (Todd, 1999) to predict escaped fire behaviour based on fuel type on WUI landscape fuel complexes. *WILDFIRE* is a contagion fire growth model first developed by Kourtz *et al*., (1977).

Spatially Explicit Burn Probability: we have developed a burn probability model that predicts the burn probability of a forest landscape in the near future based on:

- historical fire ignition patterns for human and lightning-caused fires.
- *historical weather data.*
- level of protection, *i.e*., the suppression effort existing in the landscape.
- *the present fuel type.*
- the predicted burning time that produces fires with the average annual size.

The burn probability of each raster cell of the landscape is calculated according to the fire activity obtained and the existing fuel types. This indicates where fires are more likely to occur and fire managers can design strategies to counteract them. The outputs of the burn probability model are numerical as well as spatial and the burn probabilities can be displayed on a map. Users can then evaluate the results and design new fuel management strategies: *e.g*., fuel conversion to different fuel types in some areas or fuelbreaks in different locations. By using the GIS GUI users can delineate the location of possible fuelbreaks and other fuel treatments.

Structure Fire Exposure Assessment: given the concept of shared responsibility between fire management agencies and owners for fire management in WUI areas, this assessment model contains two components. One is the probability that a fire will occur and spread in the adjacent landscape, which is influenced by the measures adopted by fire management agencies. The second component: the probability that the structure will be damaged should a fire occur is influenced by the hazard reduction strategies adopted by homeowners. To estimate the probability that a house will be damaged by a wildfire we consider two factors: the roofing and siding materials.

Fire Management Strategy a geographical information system graphical user interface (GIS GUI) specifically designed for this WUI Decision Support System, can be used to display and query information in the spatial database. The GIS GUI enables users to predict fire impact with respect to the desired criteria and help develop alternative strategies: the GIS GUI enables them to input parameters for landscape management strategies *e.g.*, the locations of firebreaks or other fuel management treatments under different scenarios.

Modified Forest Landscape Management Unit: We display the modified forest landscape and predict the potential impact of the fire activity on the modified landscape after the FireSmart strategies have been input. We predict how the burn probability will vary as a result of specific proposed fire management strategies. The physical consequences or outcomes of this modified landscape are measured in terms of expected area burned and expected structures burned.

Evaluating Alternative Strategies: in order to evaluate alternative strategies we predict the physical consequences or outcomes, *e.g.* area burned and houses damaged. The evaluation of strategies takes into account as well, how a wildfire might threaten evacuation routes. We have developed a simulation model that can be used to evaluate specified strategies, but it cannot identify an optimal strategy.

An Illustrative Example

The following example illustrates how the WUI DSS can be used. We present only the spatially explicit burn probabilities for this example since we have not yet developed the structure fire exposure assessment component of our model. The land base we are currently working with is the Romeo Malette Forest, which lies within the Northeast region of Ontario, close to the City of Timmins. The administration of the Romeo Malette Forest is the responsibility of Tembec Inc. and the Ontario Ministry of Natural Resources. Our study area is a 44 x 32 km (140,999 ha) portion of this landscape. The WUI area comprises 195.6 ha. of the study area . We partitioned the study area into a grid of 50 m by 50 m cells. Wildfire data from the Ontario Ministry of Natural Resources was used to assess burn probabilities. That data showed the area receives a level of protection of 95.5 % - 4.5% of the fires escape initial attack. We assume a uniform level of protection across the landscape.
We simulate the fire activity in this landscape (Figure 1), and obtain the spatially explicit burn probabilities shown. The probability map gives the probability, $B_{i,j}$, that a fire will burn in every cell (*i,j*) of the landscape for the near future, *e.g.*, next season. For this example 10,000 years or repetitions were used to estimate the burn probabilities across the landscape. The WUI areas are colored in blue. The highest burn probability of the landscape is 0.4%.

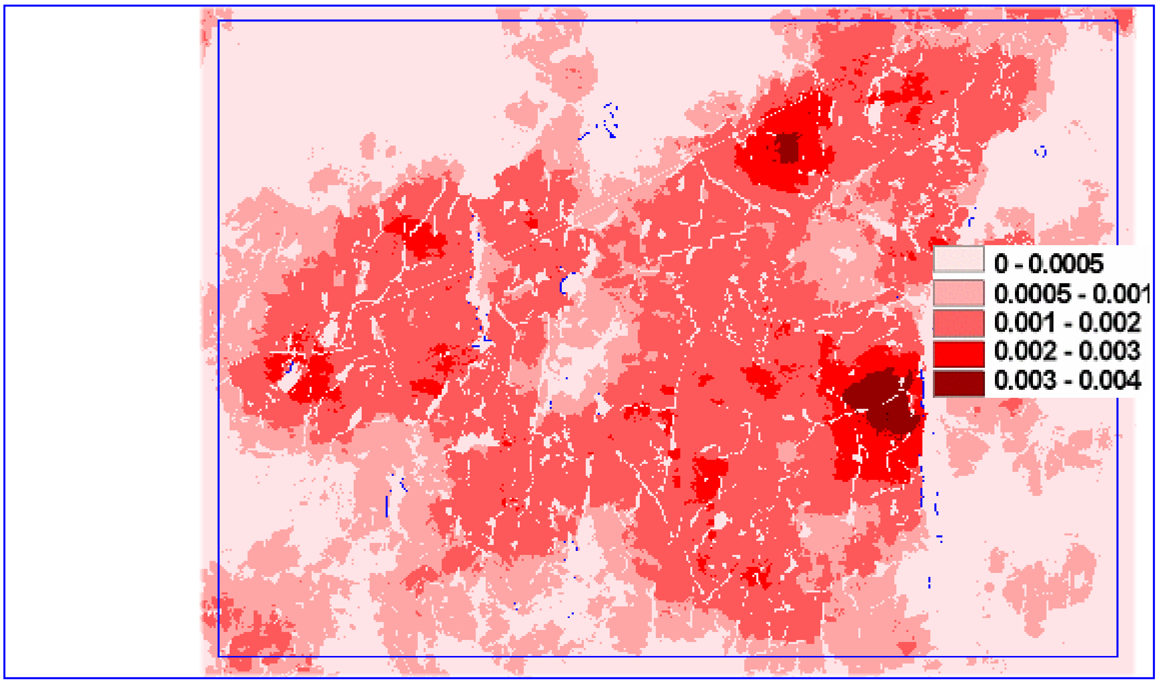

Figure 1.

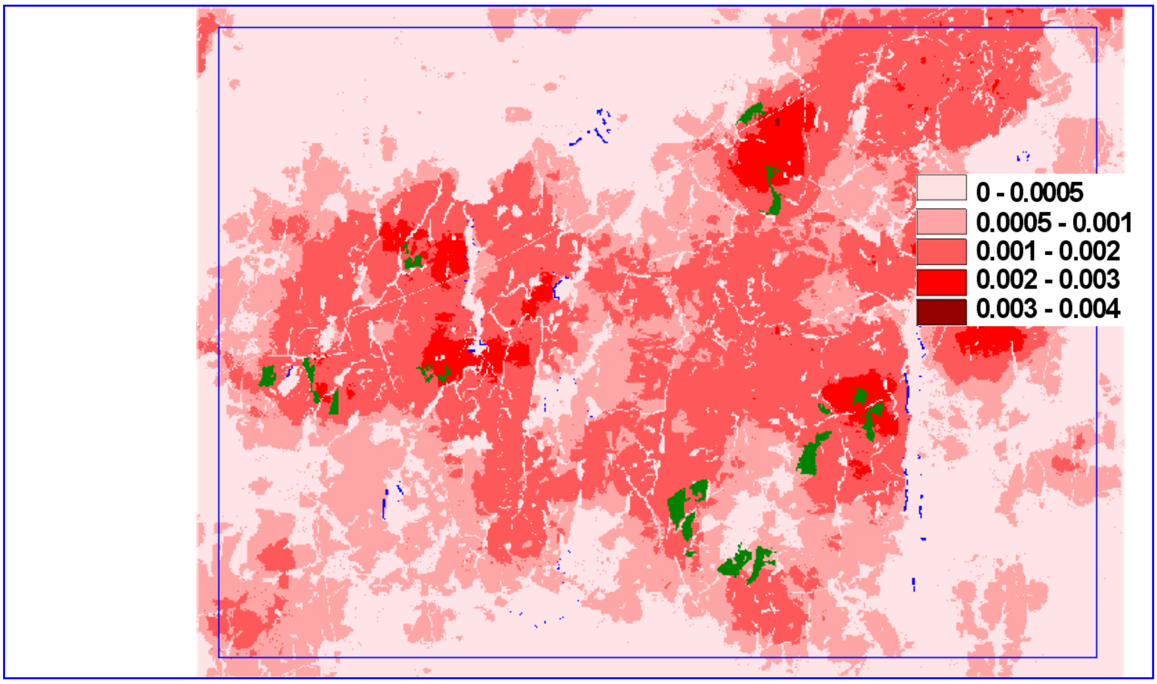

Figure 2

Knowing the location of the WUI areas and the burn probability of the adjacent landscape, we can identify some potential FireSmart strategies. Figure 2 shows the spatial distribution of the burn probability when a fuel conversion treatment is applied to a portion of the landscape. In this case the green colored stands have been converted to a less flammable fuel type. Of the total area treated, 1,191.41 ha (0.85 % of the total forested area), approximately 90% were mixedwood stands in which the percentage of deciduous species was increased and the remaining 10% were conifer stands suitable to harvest and convert to aspen stands. As a result of this strategy the burn probability map has change in both the shape and location of the probability ranges. The highest burn

probability is lowered to 0.3% and the area for the burn probability interval 0.1-0.2 % was notably diminished.
For the next strategy (Figure 3) a defensible space of 30 feet wide (9.1 m) was produced around the WUI areas. This buffer zone was considered to be non-fuel type. A significant change in both the shape and location of the probability ranges is again noticeable. The area with the highest probability (interval 0.3-0.4%) is significantly reduced as well as the area for the 0.2-0.3% burn probability interval

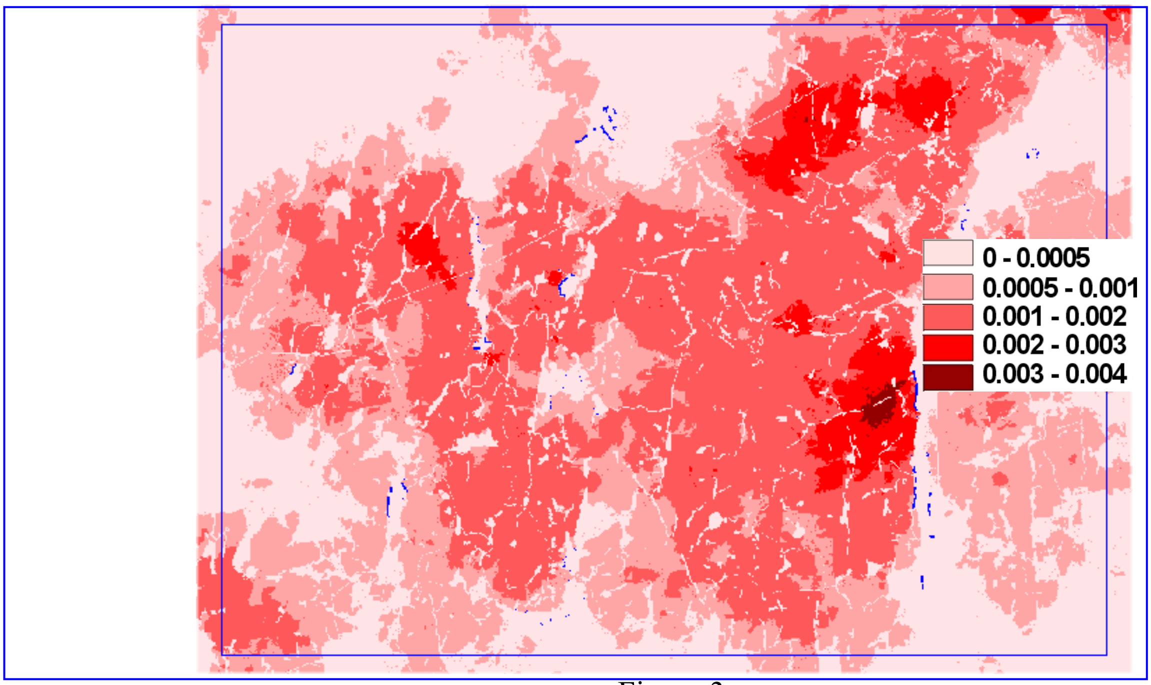

Figure 3

Applications, Further Research and Implementation

Our WUI DSS can be used to help develop and evaluate FireSmart management strategies based on the existing fire characteristics of the landscape as well as desired levels of fire hazard reduction. New residential development planning should address adequate safety for communities from existing risk of fire. Local planning agencies are responsible for the review and approval of such developments and building permits. Our WUI DSS could be used to help assess the hazard that wildfire may pose to existing and new communities in forested areas
Fire management agencies could use the WUI DSS to gain insight into the conditions under which fires occur and predict the result of different strategies. It could be used by large agencies that need broad insight concerning landscape processes and small fire agencies that require a comprehensive understanding of fire impacts. One of the strengths of our DSS is the spatially explicit graphical representation of the burn probability for the near future which can readily be understood by the general public and can perhaps be used to help motivate homeowners to implement hazard reduction measures.
We are currently enhancing the WUI DSS in a number of ways. We are currently focusing on the spatially explicit burn probability model. The fire spread model and its limitations are being assessed and the GIS GUI is being enhanced in order to facilitate

the input of strategies. Further research will be needed to explore the economic aspects of WUI fire management.

Conclusions

Fire management in WUI landscapes is both complex and challenging. The objective of our WUI Decision Support System is to provide land management planners and fire managers with a decision support system that can be used to help develop and evaluate strategies for WUI landscapes that are threatened by wildfire.
As a result of the analyses and tools developed for this system a better understanding of the fuel management processes from landscape perspectives achieved. Considering the specific attributes of WUI areas, our model will contribute to improved fire management and reduce threats to public safety in WUI landscapes.

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