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Using Risk Analysis to Reveal Opportunities for the Management of Unplanned Ignitions in Wilderness

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A goal of fire management in wilderness is to allow fire to play its natural ecological role without intervention. Unfortunately, most unplanned ignitions in wilderness are suppressed, in part because of the risk they might pose to values outside of the wilderness. We capitalize on recent advances in fire risk analysis to demonstrate a risk-based approach for revealing where unplanned ignitions in wilderness pose little risk to nonwilderness values and therefore where fire can be managed for its longer term ecological benefits. Using a large wilderness area as a case study, we conduct an exposure analysis and quantify the potential for unplanned ignitions inside the wilderness area to spread outside the wilderness boundary onto adjacent lands. Results show that, in general, ignitions that occur inside a large core area of the wilderness have very low likelihoods of escaping the wilderness boundary, especially early and late in the fire season. These "windows" may thus represent opportunities for allowing natural fire to occur. We discuss our approach in the broader context of spatial fire risk management and planning across public lands.

Keywords: wildland fire, exposure analysis, spatial fire planning, escape probability

Managing fire as a natural ecosystem process while minimizing its risk to resources and assets has proven to be difficult for public land management agencies. Despite the well-documented negative effects of suppression in several forest types, it remains the dominant management response to wildland fire across public lands (Gilliam and Platt 1999, Keane et al. 2002). A passive forest restoration model of reintroducing fire into fire-adapted ecosystems, particularly in dry forests of the western United States, has been proposed to create and maintain resilient forests (Cocke et al. 2005, Naficy et al. 2010, Larson et al. 2013). In such forests, restoring the process of fire can result in "self-limiting" landscapes that exhibit negative feedbacks between fire and subsequent fire spread and severity (Peterson 2002, Collins et al. 2009, Parks et al. 2015). This passive restoration approach is especially applicable in federally designated wilderness areas because these areas are supposed to be managed for natural processes with minimal human intervention (Parsons et al. 2003, Collins and Stephens 2007). However, the majority of unplanned ignitions in wilderness, including those started naturally by lightning, are suppressed (Miller and Landres 2004, Miller 2012). As a result, opportunities to manage fire for its longer-term ecological and fuel treatment benefits (e.g., Parks et al. 2014, 2015) are routinely foregone.

Current federal fire policy stipulates that fire and its management will be integrated in land or resource management plans (L/RMP) on a landscape scale (US Department of Interior et al. 2001). Policy also requires that every area with burnable vegetation must have an approved fire management plan (FMP), which is subordinate to the L/RMP. Although it varies among federal agencies (Meyer et al. 2015), L/RMPs typically articulate, in very general terms, the desired role of fire for particular areas. The FMP then outlines specific strategies and tactics that will meet the resource goals and objectives of the L/RMP. FMPs are commonly organized by zone or management unit and define the areas where and the conditions under which it is appropriate to use unplanned ignitions to meet natural resource objectives (Fire Executive Council 2009). Often, the definition of these areas and conditions are based on an assessment or

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evaluation of risks and hazards which can be updated annually to reflect changes in fuels and values of concern (Scott et al. 2013). As such, both the L/RMP and FMP importantly set the overall tone for the operational management response to fire, even though actual response to an unplanned ignition will be informed by situational assessments and risk analyses that reflect real-time conditions (Taber et al. 2013).

One major reason lightning-ignited fires in wilderness are suppressed is their potential to negatively affect resources and assets adjacent to the wilderness (Agee 2000, Miller and Landres 2004, Black et al. 2008). The situation is exacerbated by the interacting trends of increased fuels and fire hazard resulting from historical fire exclusion (Stephens 2005), increased housing development proximate to protected areas (Radeloff et al. 2010), and shifting climatic patterns that have lengthened and intensified fire seasons (Westerling et al. 2006). Furthermore, increasing sociopolitical pressure to reduce fire suppression expenditures can encourage initial-attack response because, if successful, it can be an inexpensive, albeit short-term, solution (Gebert and Black 2012). Collectively, these factors contribute to a feedback loop where suppression strategies are increasingly favored, fuels continue to accumulate, and fire risk increases (Arno and Brown 1991).

The judicious use of wildland fire has been proposed as a way out of this feedback loop (Calkin et al. 2015). An analysis of risk is central to this proposition, and contemporary federal fire management policy guidance in the United States directs land management agencies to make risk-informed decisions for all fire management activities (Fire Executive Council 2009). Fire risk is formulated by integrating the likelihood, intensity, and effects of fire (both positive and negative) on market and nonmarket resources at risk (Scott et al. 2013). Recent advancement in the science and technology of fire risk assessment has enabled the development and use of geospatial decision-support tools (e.g., Ager et al. 2011, Calkin et al. 2011, Finney et al. 2011a, Noonan-Wright et al. 2011), allowing fire risk to be explored over space and time under alternative landscape scenarios. Furthermore, spatial fire planning is seen as a way to provide fire managers with specific guidance for implementing fire-related direction, and an assessment of risk is a necessary component (US Department of Agriculture [USDA] Forest Service 2014).

At the core of geospatial fire risk decision-support tools are stochastic Monte Carlo simulation models that produce high-resolution maps of burn probability (BP) (Miller et al. 2008). BP models simulate the propensity for areas on the landscape to experience fire, incorporating the dynamics of ignitions and weather on fire spread for a static landscape condition (i.e., topography and fuels). In addition to BP maps, some BP models provide vector outputs for each individual simulated fire, including its final perimeter, start date, and ignition location. This additional information allows a more nuanced analysis of landscape fire risk that can be linked to a specific ignition or group of ignitions. In one recent example, Thompson et al. (2013b, p. 630) used vector outputs from the simulation system FSim (Finney et al. 2011b) to delineate a spatial "fireshed" for a rare butterfly's designated critical habitat in the state of Colorado, and defined the fireshed "as the land area where a fire can occur and eventually spread to a defined point, line, or polygon." Vector outputs from FSim were also used by Scott et al. (2012) to evaluate the likelihood of unsuppressed ignitions starting in different months spreading into wildland-urban interface (WUI) zones surrounding the community of Jackson, Wyoming. Haas et al. (2014) mapped the level of human population exposed to unplanned ignitions along the Colorado Front Range under extreme fire weather conditions, whereas Ager et al. (2014) summarized the transmission of ignitions on national forests to nonfederal lands and WUI areas.

This study complements these recent efforts by characterizing the likelihood of unplanned ignitions in wilderness reaching a specific point of concern: the wilderness-nonwilderness boundary. Using output from the fire simulation system FSim (Finney 2011a), we quantify and map the likelihood that unsuppressed ignitions starting inside a designated wilderness area will spread and escape across the wilderness boundary. We then classified and identified areas within the wilderness where the likelihood of fires escaping the boundary is especially low, thus revealing where opportunities might exist to allow unplanned ignitions to burn. We demonstrate our approach with results from a case study in the Selway-Bitterroot Wilderness in Idaho and Montana and discuss the utility of our approach in the broader context of fire risk management of unplanned ignitions across public lands.

Methods

Case Study Area

The 1,340,497 acre Selway-Bitterroot Wilderness (SBW) straddles the Montana-Idaho border, forming the third largest wilderness area in the conterminous United States (Figure 1). A wide diversity of vegetation types are found in the SBW due to its complex topography and wide climatic gradients. Elevations range from roughly 1,800 to 10,000 ft across the study area. The eastern portion of the SBW is dominated by the rugged north-south oriented Bitterroot Mountains containing glaciated east-west drainages. The Selway River basin drains major portions of the southern and central portion of the SBW, consisting of diverse mountainous terrain with high ridges and deep river valleys.

Climate varies from inland-maritime in the northwest portion of the SBW to conti-

Management and Policy Implications

Fire management plans need to address the location and conditions under which resource objectives can be met with fire. The exposure analysis demonstrated here helps meet this need by identifying "windows of opportunity" for using unplanned ignitions to meet natural resource management objectives. In addition, it integrates well with spatial fire planning (USDA Forest Service 2014) activities that are increasingly being adopted to support both preseason planning and real-time incident management decision environments and can be updated on an annual basis to reflect current fuel and vegetation conditions. Implementing these methods in small wilderness areas or wilderness areas adjacent to wildland-urban interface zones may reveal previously unrecognized opportunities for allowing unplanned ignitions to burn. Forest managers can use such findings to amend existing fire management plans to expand the use of unplanned ignitions to meet resource objectives. Although this approach was demonstrated in the context of wilderness fire management, it has broad applicability and could support spatial fire and fuels management planning efforts in nonwilderness settings.

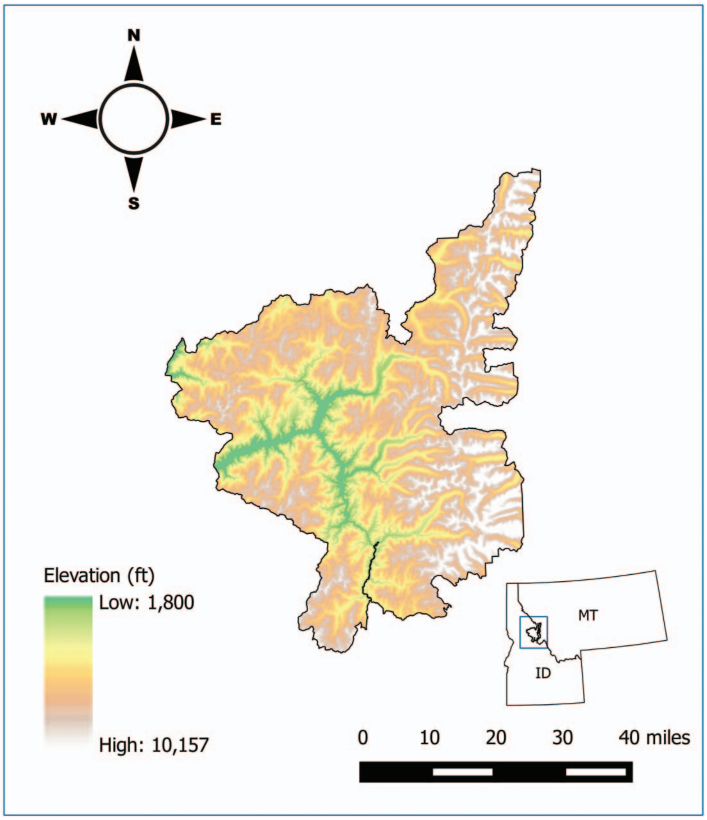

Figure 1. Map of case study area.

nental in the southeast (Finklin 1983). Forest vegetation transitions along an elevation gradient from stands of ponderosa pine (*Pinus ponderosa*) to mixed conifer forests, with subalpine fir (*Abies lasiocarpa*), whitebark pine (*Pinus albicaulis*), and subalpine larch (*Larix lyallii*) found in the highest elevations. The area experiences a mixed-severity fire regime (Brown et al. 1994). Both lethal and nonlethal surface fires occur at lower elevations depending on fuel and weather conditions, whereas stand-replacing fire is common in the upper elevation forest types. The fire management history in the SBW is unique in that it was here where the first attempts were made by the USDA Forest Service to use fire as a management tool, as opposed to the de facto management response of suppressing natural fire. These early pioneering efforts have resulted in the SBW being one of the premier landscapes to study the effects of restoring natural fire regimes after the reintroduction of fire in 1972 (Miller 2014). Today, however, some natural fires are still suppressed in the SBW due to perceived threats of long-duration, large fire events on resources and assets outside the wilderness boundary.

Fire Simulation Model

The fire simulation system FSim (Finney et al. 2011b) was used to model the occurrence and growth of unsuppressed fires across 10,000 simulated fire seasons. FSim integrates existing models of fire occurrence (Andrews et al. 2003) and growth (Finney 2002) with statistically generated weather streams (Grenfell et al. 2010) to simulate the ignition and spread of individual fires. The modeling system requires spatial data layers that describe fuels, vegetation, and topography for use in its fire spread algorithm. Annual and interannual variability in fire weather is captured through simulated weather streams, which are generated based on a time-series analysis of an historical fire danger index from the National Fire Danger Rating System known as the Energy Release Component (ERC) (Cohen and Deeming 1985). Historical weather data are also used to develop joint distributions of wind speed and direction that are then randomly sampled for each day of simulated fire growth. In the version of FSim used here, unsuppressed simulated fires self-extinguish after 2 days of nonburnable conditions (i.e., simulated ERC less than the 80th percentile) in nonforest fuels and after 7 days of nonburnable conditions in forest fuels. Ignition locations are randomly selected by default in FSim, but users can optionally provide a nonrandom ignition density grid to more accurately represent the spatial distribution of ignition locations. Outputs from FSim include raster grids of annual burn probability and mean fireline intensity, as well as individual simulated fire perimeters in vector format, each with additional descriptive information (i.e., ignition location, start day, and final fire size). Validation exercises have demonstrated FSim's ability to successfully reproduce distributions of historical fire sizes and annual area burned (Finney et al. 2011b).

Model Inputs

FSim requires a set of eight spatial data layers representing fuels, vegetation, and topography, which are collectively referred to as a "landscape file": fire behavior fuel model, canopy base height, canopy bulk density, forest canopy cover, forest canopy height, elevation, aspect, and slope. We obtained the requisite spatial data layers representing forest and vegetation conditions in the SBW as of 2010 from LANDFIRE, version 1.2.0.[1] All data layers were at a 30-m (98.4-ft) spatial resolution. A rectangular spatial buffer extending approximately 25 miles from the wilderness boundary was applied to the study area (size = 8,601,040 acres).

To create the weather files required by FSim, we used weather data between 1992 and 2012 from the Powell Remote Automated Weather Station (RAWS), located in the northern portion of the SBW. Although other RAWS within the study area exist, many of them lack a consistent data record over time or are situated in positions such that the data would not accurately represent weather across the entire study area (e.g., heavy topographic influence). The Powell RAWS was deemed to most accurately reflect potential fire weather across the study region.

To represent the spatial distribution of ignitions within the study area, we supplied FSim with a spatially explicit ignition probability grid developed from data for ignitions that occurred between 1992 and 2012. These data were obtained from a spatial database maintained by the interagency Fire Program Analysis system (Short 2014). The probability of an ignition was estimated using kernel density with a Gaussian kernel

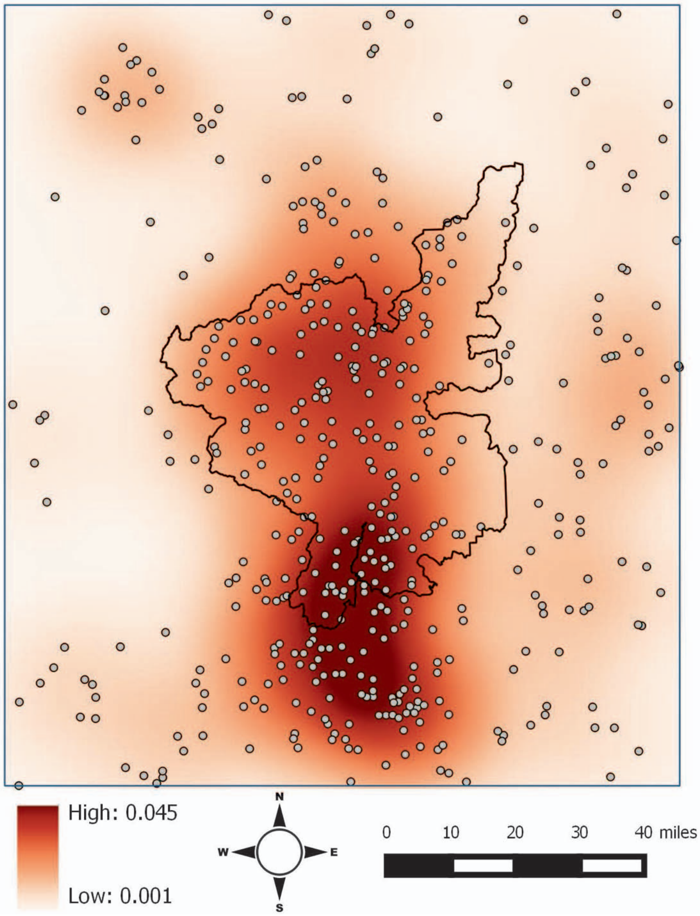

Figure 2. Ignition locations for all fires between 1992 and 2012 of ≥200 acres used to derive ignition density grid values within the FSim modeling extent.

Table 1. Comparison of historical and simulated large-fire (>500 acres) statistics.

	Historical	Calibration	Final
Mean annual large-fire area burned (acres)	120,951	101,899	157,968
Mean annual number of large fires	16.62	14.43	17.75
Mean large-fire size (acres)	7,278	7,063	8,899

Simulated large-fire statistics are presented with the FSim suppression module enabled during calibration (calibration), and when subsequently turned off for final analysis (final).

function (search radius = 18.64 mi). This produced a smoothed grid representing the probability of an ignition occurring at each point on the landscape (Figure 2).

Simulations were performed at a 270-m (886-ft) spatial resolution. We set the maximum fire size limit to 500,000 acres so that simulated fires may exceed the largest fire observed in the historical record (276,000 acres) within reason. Live fuel moisture values were adjusted, assuming lower curing rates in live herbaceous and live woody fuel types, and dead fuel moisture values for timber fuel models were slightly increased to reflect higher dead fuel moisture content under closed canopies than for the Powell RAWS. The suppression module in FSim was used during calibration to reflect contemporary fire management. This module implements a containment probability model (Finney et al. 2009) that predicts the daily likelihood of containment based on current and previous fire spread. Successful containment occurs when the predicted probability of containment is greater than a random draw. We calibrated final model parameters based on a comparison of historical and simulated large-fire (greater than 500 acres) statistics. In the final simulation, we used the calibrated model parameters but with the suppression module turned off (Table 1). Although calibration was informed by simulated large-fire statistics, we retained all simulated fires to derive escape probability.

Mapping Escape Probability

Ignitions simulated in FSim that started within the SBW and whose simulated perimeters subsequently breached the wilderness boundary by any amount were identified as "escapes." A 7,670-acre circular moving window was then passed over the simulated ignition point data, and the window's center grid cell was populated with values representing the proportion of ignitions within the window that escaped the wilderness boundary. We chose a relatively large window size to generate a smooth escape probability grid surface in an effort to conservatively estimate escape probability at each point on the landscape. Escape probability was calculated for all grid cells inside the wilderness boundary.

Resulting maps of escape probability were created for each month of the fire season based on ignition date. Contour lines were subsequently fit at specified escape probability thresholds (0.01, 0.05, 0.10, 0.25, and 0.50) to classify the landscape into zones of escape probability. We summarized escape probability in terms of escaped fire size, distance to the wilderness boundary, month of ignition, and proportion of the study area in each escape probability class.

Results

The 10,000 yearly simulations produced a total of 393,534 individual fires with an average fire size of 4,102 acres (median = 378 acres). The simulated average annual number of fires and area burned were 39.35 and 161,478 acres, respectively. A total of 130,605 simulated ignitions were located inside the wilderness boundary; 12,115 of these fires were identified as escapes (Figure 3).

Spatial Patterns of Escape Probability among and within Simulated Fire Seasons

The likelihood of ignitions escaping the wilderness boundary was lowest in the interior core area of the wilderness and highest along and proximate to the wilderness boundary (Figure 4). Although this pattern tended to follow the shape of the wilderness boundary, it was somewhat variable with contours of relatively higher values extending further into the wilderness on the southern portion than on the eastern.

A similar spatial pattern was seen when

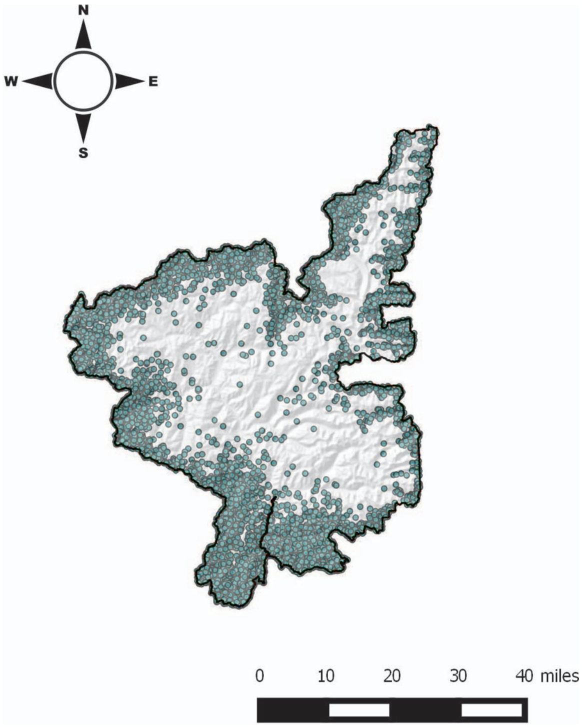

Figure 3. Locations of simulated ignition points whose perimeters breached the wilderness boundary.

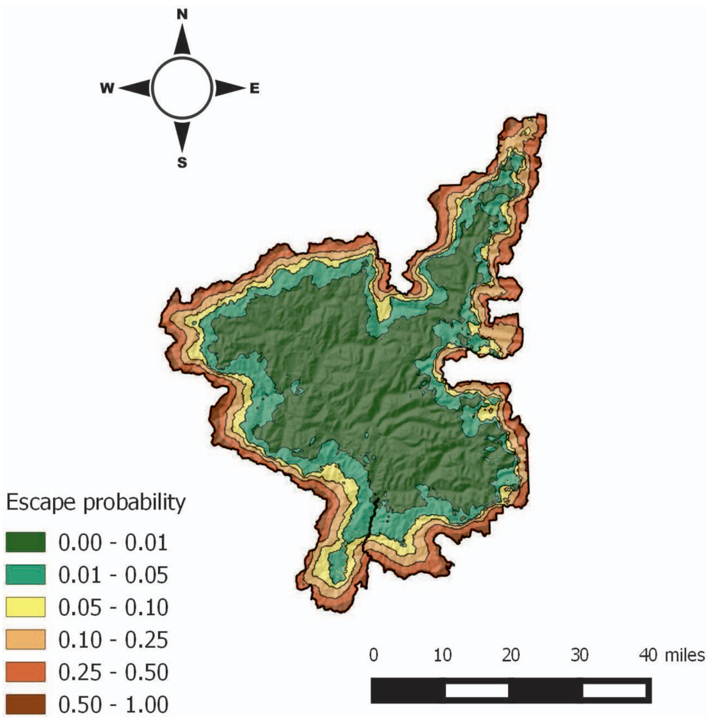

Figure 4. Map of the likelihood of unsuppressed ignitions spreading outside the wilderness study area boundary across all months in simulated fire seasons.

escape probability was stratified by ignition date, although the locations of specific contour lines varied by ignition month (Figure 5). Spatially, the area with the lowest escape probability was restricted to the core of the wilderness for the mid fire season months (July–August) and was larger during the early (May–June) and late fire season months (October–November).

The likelihood for an ignition to escape the wilderness was nonlinearly related to its distance to the wilderness boundary (Figure 6). The maximum distance between an escaped ignition and the wilderness boundary was about 16 miles. There was substantial variability in escape probability, especially at close distances to the wilderness boundary.

Month of Fire Season and Escaped Ignitions

Of the 130,605 ignitions that started inside the wilderness, a small percentage (9.3%) were classified as escapes. This percentage varied by month of ignition (Table 2). Wilderness ignitions in the middle of the fire season (July–August) were most likely to spread outside the wilderness. The likelihood of an escaped fire increased between May and August and then sharply declined in each of the following months. Mean escaped fire size was greatest for August ignitions. Simulated ignitions before the end of August accounted for 80.7% of all escaped ignitions, and nearly all escaped fires had ignited before the end of September.

Classifying the Wilderness Landscape Based on Risk of Escaped Ignitions

A high proportion of the SBW (41.6%) was in the lowest escape probability class (values <0.01), whereas only 4.2% of the wilderness was in the highest escape probability class (values >0.50) (Table 3). Estimates varied throughout the fire season.

Discussion

Important advances have been made in fire risk assessment, leading to the development of decision-support tools with potential application to a broad range of fire management policy questions, including fuels management (Miller and Ager 2013). In designated wilderness where the use of mechanical fuel treatments and prescribed fire to reduce fuel loads is prohibited, the most appropriate option for managing fuels and fire risk is through the use of unplanned ignitions (Miller 2006), but the application of risk analysis tools to identify where opportunities for that option exist is still new. Recent applications of fire risk analysis have assessed the exposure of resources and assets to unplanned ignitions, introducing novel approaches to characterize exposure of unplanned ignitions in terms of space (e.g., Thompson et al. 2013b, Haas et al. 2014) and time (e.g., Scott et al. 2012). In this article, we complement these efforts by demonstrating an approach to map the likeli-

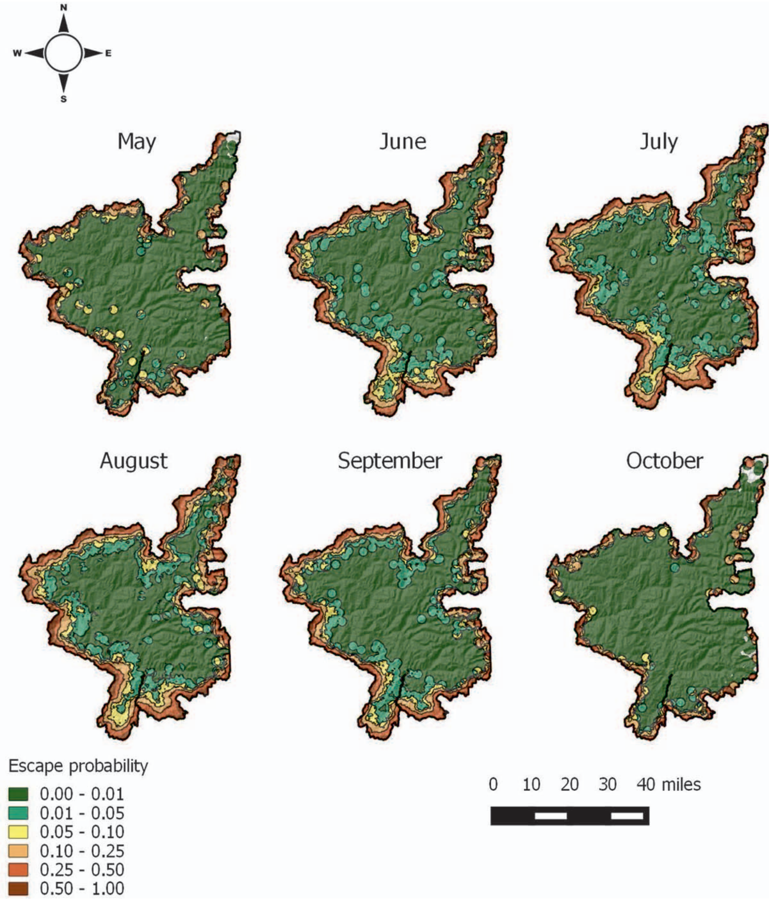

Figure 5. Maps of the likelihood of unsuppressed ignitions spreading outside the wilderness study area boundary for each month of ignition in simulated fire seasons.

Figure 6. Scatterplot of escape probability versus distance to the wilderness boundary.

hood of unsuppressed, unplanned ignitions reaching a point in space (i.e., the wilderness boundary) and summarized how this likelihood varies with ignition date.

Our results complement earlier work showing that the risks of allowing unsuppressed ignitions to burn vary according to when they start in the fire season, not just their location (Scott et al. 2012). Midseason fires were more likely to become large and spread outside the wilderness boundary compared with early or late season fires (Table 2). Not surprisingly, the low number of possible fire spread days prevented late season ignitions from becoming large and escaping the wilderness. Early season ignitions had ample time to become large fires, but lacked the requisite continuity in simulated weather conditions to do so.[2] Results further suggest that there are large areas inside the SBW where the risk of unsuppressed ignitions escaping the wilderness is very low during early fire season months (Figure 5).

The SBW case study area used for this analysis is one of the largest wilderness areas in the conterminous United States, with an extensive network of fuel breaks created by previous fires and natural features; not surprisingly, our results indicate ample opportunities for managing long duration wilderness fires. Unfortunately, this practice has been limited to only a handful of relatively large wilderness areas in the western United States (Calkin et al. 2015). The insights provided by this analysis may prove to be especially useful in much smaller wilderness areas and/or wilderness areas adjacent to WUI zones where low-risk opportunities to manage fire are less apparent. By characterizing fire risk in terms of spatial zones and temporal windows, this approach could reveal opportunities for allowing unplanned ignitions to burn even if those opportunities are confined to specific locations and times of the year (Miller and Aplet 2016).

Federal fire management policy guidance states that unplanned natural ignitions may be managed to achieve resource objectives when the risk is within acceptable limits (Fire Executive Council 2009). However, the guidance does not specify how to determine these limits. Acceptable levels of escaped fire risk are likely to vary among management units, geographic regions, and individual fire managers due, in part, to past history and varying levels of experience and comfort with less aggressive fire management strategies. For example, the acceptable level of risk to an administrator of a wilderness area with an established fire use program may be greater than that for an administrator of a wilderness without such a history. With our use of the value of 1% for the first contour on the maps of escape probability, we implicitly assumed that this may be an acceptable level of risk for managers and society. These contour values, however, can be adjusted to reflect varying levels of risk aversion. Moreover, we acknowledge that risk is not just exposure; understanding potential fire behavior and fire effects is also an important component of fire risk management (Miller and Ager 2013, Scott et al. 2013).

Although this approach was demonstrated in the context of wilderness fire management, it also has broad applicability to support fire and fuels management planning efforts in nonwilderness settings. Constraints to managing unplanned ignitions in nonwilderness landscapes are likely to vary both among and within public land management agencies depending on management objectives and resources and assets at risk. Assuming that these values-at-risk can be ac-

Table 2. Summary statistics for ignitions inside the study area across simulated fire seasons.

Month of ignition	Total ignitions	No. of escapes	Proportion of escapes	Mean escaped fire size (acres)	Cumulative probability of escape
May	5,867	410	0.070	11,691	0.034
June	23,729	2,065	0.087	15,679	0.204
July	34,019	3,405	0.100	19,351	0.485
August	36,556	3,899	0.107	20,675	0.807
September	24,052	2,025	0.084	10,670	0.974
October	6,229	306	0.049	3,504	0.999
November	153	5	0.033	583	1.00
Entire season	130,605	12,115	0.093	17,033	NA

Table 3. Proportion of the study area by escape probability class and month of ignitions across simulated fire seasons.

Month of ignition	Escape probability class					
	0.00–0.01	0.01–0.05	0.05–0.10	0.10–0.25	0.25–0.50	0.50–1.00
	(%)					
May	70.8	3.6	6.4	8.8	7.6	3.0
June	46.1	17.5	10.3	11.6	10.2	4.3
July	40.5	20.2	9.1	12.9	12.5	4.9
August	38.7	19.2	10.4	13.1	12.4	6.2
September	49.8	16.3	8.2	11.3	11.1	3.3
October	79.2	2.2	4.1	7.9	5.2	1.4
Entire season	41.6	20.4	9.3	12.4	12.0	4.2

curately identified and represented with spatial data, the approach outlined in this article could be used to quantify the spatiotemporal likelihood of unplanned ignitions reaching jurisdictional or landownership boundaries and other at-risk areas. This exposure analysis could be used as a complement to other preseason preparedness and spatial fire planning efforts to assess landscape-level fire risk (USDA Forest Service 2014).

The escape probability maps we presented were generated from many thousands of simulated fire seasons that used historical data on fire occurrence, area burned, and weather (Finney et al. 2011b). The intent was to capture a wide of range of possible outcomes resulting from highly variable ignition location and fire weather patterns. Accordingly, escape probability should be interpreted as the average likelihood of an unsuppressed ignition spreading outside the wilderness for "all" known fire weather conditions, and thus is useful for long-term strategic fire management planning. Different tools are needed to support incident management and to guide initial-attack responses to unplanned ignitions, such as maps that depict the conditional likelihood of fire spread based on real-time forecasted weather patterns (e.g., FSPro) (Finney et al. 2011a). Furthermore, because model outputs are derived from historical fire weather data, they may not accurately capture future fire escape probabilities in an era of a warming climate and longer fire seasons (Krawchuk et al. 2009, Moritz et al. 2012). Finally, since FSim does not simulate ignitions below the 80th percentile ERC, we may be underestimating escape probability during early and late fire season months depending on the historical occurrence of large fires that ignited below this threshold.

Quantitative risk analyses continue to improve with more accurate input data and refined simulation frameworks. Any improvements made in the field of BP modeling will undoubtedly increase the reliability of their derived products, such as the escape probability maps presented here. Advancements like the use of gridded weather data, improved fire spread algorithms, or better accounting of changing fuel moisture conditions would all increase the validity of the final results. The utility of fire risk analysis is also constrained by the limited historical weather data record that is necessary to validate model outputs (Thompson et al. 2013a), and the variable quality of input data oftentimes requires additional calibration to accurately reflect recent changes in fuels and vegetation due to disturbance and management actions. Given these potential limitations, our modeling approach may be most suitable in areas with detailed fuels data that have been thoroughly critiqued and adjusted to more accurately reflect on-the-ground conditions, and in areas with extensive local fire knowledge to further evaluate model outputs.

Conclusion

Reintroducing fire into fire-adapted ecosystems is an inherently risky endeavor, primarily because of the chance that fires will spread to undesirable areas on the landscape. In the context of wilderness and other protected areas, the risk of an unplanned ignition spreading onto adjacent lands oftentimes results in prompt suppression, which ultimately prevents the achievement of long-term land management goals. As we demonstrated here, decision-support tools currently available to wilderness fire managers can be adapted to identify low-risk opportunities to allow natural ignitions to burn. This information can be used to inform land management planning revisions and the development of fire management plans. An extension of this approach that identifies spatiotemporal opportunities to allow unplanned ignitions to burn in nonwilderness landscapes with additional constraints to the use of fire may prove especially useful in future applications of fire risk analysis.

Endnotes

1. For more information, see www.landfire.gov.
2 Recall that simulated ignitions in FSim self-extinguish after 2 days of nonburnable weather conditions, defined as ERC <80th percentile, in nonforest fuels and after 7 days of nonburnable weather conditions in forest fuels.

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