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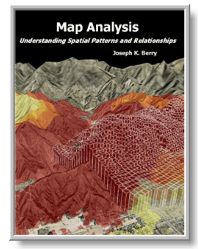

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Understanding Spatial Patterns and Relationships (Berry, 2007 GeoTec Media)

Mapping a Firewall: *Modeling and Visualizations Assess Wildfire Threats, Risks and Economic Exposure*

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In the 2007 fire season, San Diego County alone saw 360,000 acres burned, more than $1 billion in losses, more than 1,200 homes destroyed, many buildings and critical infrastructure lost, and significant amounts of commodity agriculture ruined. Suppression costs at the federal level have surpassed $1 billion annually for the last several years, and state and local costs are believed to be more than double that.

The consequences of wildfires have never been greater as more people move into wildfire-prone areas. And there's an increasing need for fuel treatments, mitigation planning, prevention awareness and recovery preparedness to reduce wildfire risk and impacts to these communities.

But where is the greatest risk? What are the potential economic, social and environmental impacts? What and where are mitigation actions most needed? How can alternatives be quantified, compared and prioritized? Are we spending our budgets effectively and efficiently?

This article focuses on the utility of geotechnology, map-analysis procedures, and Web-based visualization and delivery options to identify areas of greatest jeopardy as well as quantify the dollar impact of wildfire loss and proposed mitigation efforts.

Wildfire Threat and Risk Modeling

Previous wildfire risk models developed a relative scale, such as the low, medium, high and extreme fire-danger levels seen at the entrances of national forests. Although this scale is useful for informing the public and guiding broad fire planning, it doesn't fully express wildfire risk. Comprehensive risk modeling involves three distinct elements:

1) Wildfire Threat—estimating the probability and intensity of a wildfire occurring at a location.
2) Wildfire Effects—quantifying the impact of the potential loss.
3) Wildfire Risk—combining the threat and effects into a measure of probable loss over time.

The Wildfire Threat portion integrates numerous mapped data layers such as weather factors, historical fire occurrence, surface and canopy fuels, terrain, and suppression effectiveness based on historic fire protection (see Figure 1). A previous GeoWorld article (*Quantifying Wildfire Risk, December 2005*) described the fundamental approach and data layers involved in spatially modeling wildfire threat.

Note that Wildfire Effects is subject to change based on the characteristics and priorities of the specific geographic area. As such, Figure 1 only provides an example of common fire-effects inputs. The current enhanced model had input from an actuarial statistician and a risk-modeling expert with considerable experience in risk mapping for the insurance industry. The modifications incorporated advanced techniques, such as dynamic elliptical windows for calculating wildfire probability based on fire-behavior parameters, adjustments for urban-area partial windows and refinements for handling non-burnable areas.

This expanded perspective fully integrates remote sensing, current fire-science research, actuarial statistics and GIS expertise. The solution involves vector and raster data layers and processing procedures as well as integration with the standard LANDFIRE Program datasets. As a result, the output maps are useful to a broader group of users, ranging from traditional wildfire professionals to county land-use planners, insurance industry agents and all levels of government decision makers.

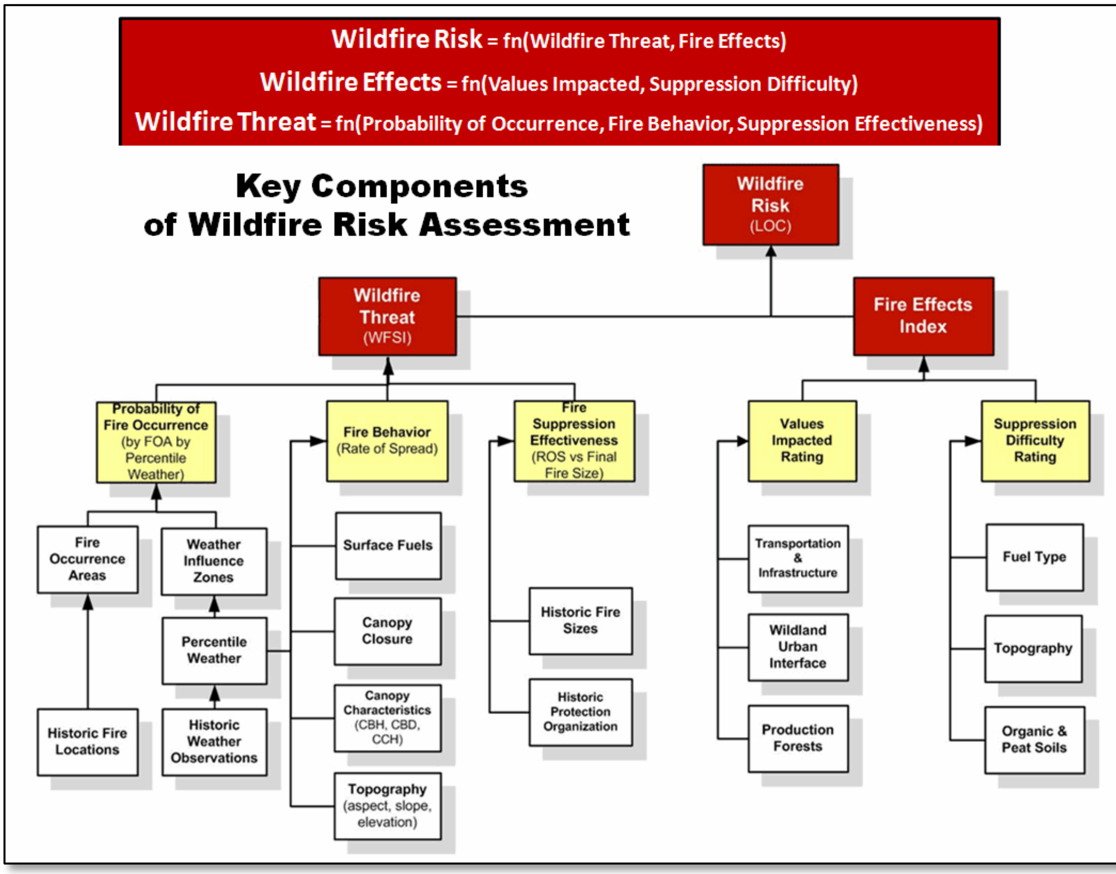
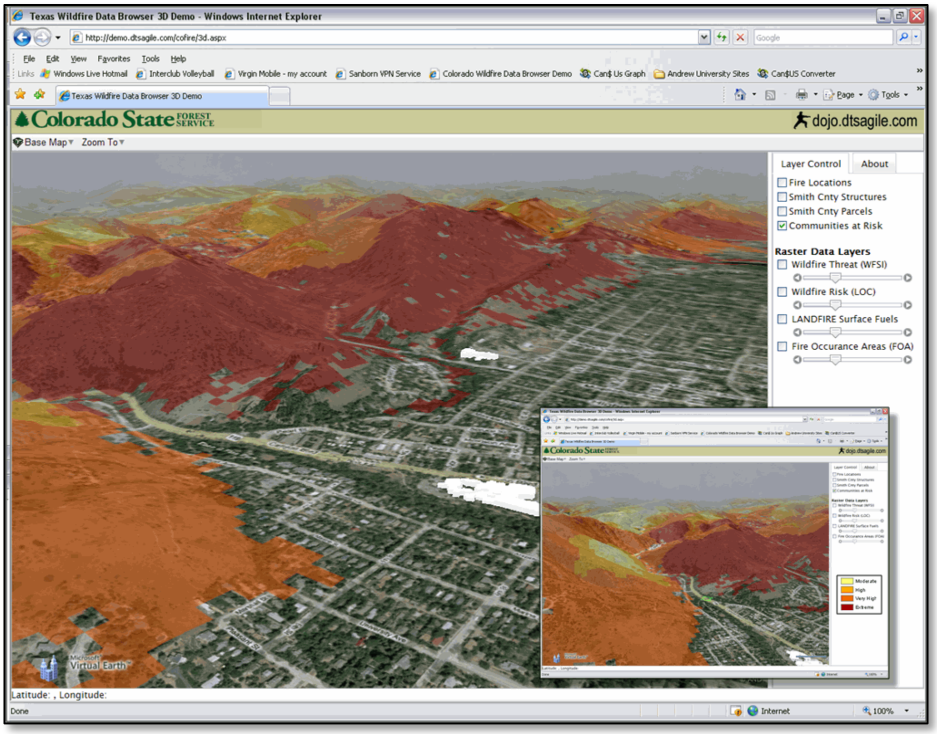


Figure 1. A flowchart depicts the key components of Sanborn's Wildland Fire Risk Assessment System.

Visualizing Wildfire Risk Outputs

Traditionally, GIS has been used to display the outputs of models, such as wildfire risk, using desktop software applications. Recent advancements have led to the delivery of thematic maps using Web-mapping interfaces on the Internet (although there are few examples for wildfires).

With the advent of 3-D globes and related public Web-mapping capabilities (e.g., Google Earth, Microsoft's Virtual Earth (Bing! Maps) and ArcGIS Online), the public and professionals now have an expectation of Web-mapping capabilities and availability. This explosion in Web mapping with multi-resolution imagery backdrops has made the consumer "spatially aware" and set the baseline for delivering Web-mapping products.



<u>Figure 2</u>. A Virtual Earth visualization of Wildfire Threat maps provides interactive access and processing for a variety of fire professionals, land planners and the general public.

Figure 2 shows an example of a wildfire threat map superimposed on the terrain for Boulder, Colo., using public Web-mapping capabilities in Microsoft's Virtual Earth map interface. Capabilities exist to integrate thematic risk maps with the underlying imagery-based map interface, including enhancements that show real-time weather information, such as cloud cover or NEXRAD data.

Figure 3 shows wildfire risk outputs from the Southern Wildfire Risk Assessment superimposed over the perimeter of the recent Highway 31 Fire in South Carolina. The prototype uses ESRI's Silverlight interface for ArcGIS Server combined with ArcGIS Online imagery services. The integration of active or real-time data provides greater context for using wildfire risk assessment data, providing tactical utility in addition to conventional planning uses.

The maps can be served via the Internet and accessed by a variety of users: the general public, county planners, and emergency-response and wildfire professionals. By varying the transparency of the wildfire risk output layers, the relative visual prominence of the underlying land cover and features can be adjusted.

This easily accessed format facilitates a user's ability to "fly through" the wildfire threat information, zoom in to an area of interest and assess the relative patterns within a context of its surrounding conditions and features. The threat values can be expressed as traditional wildfire danger ratings (low, moderate, high) or as the discrete probability of a wildfire occurring.

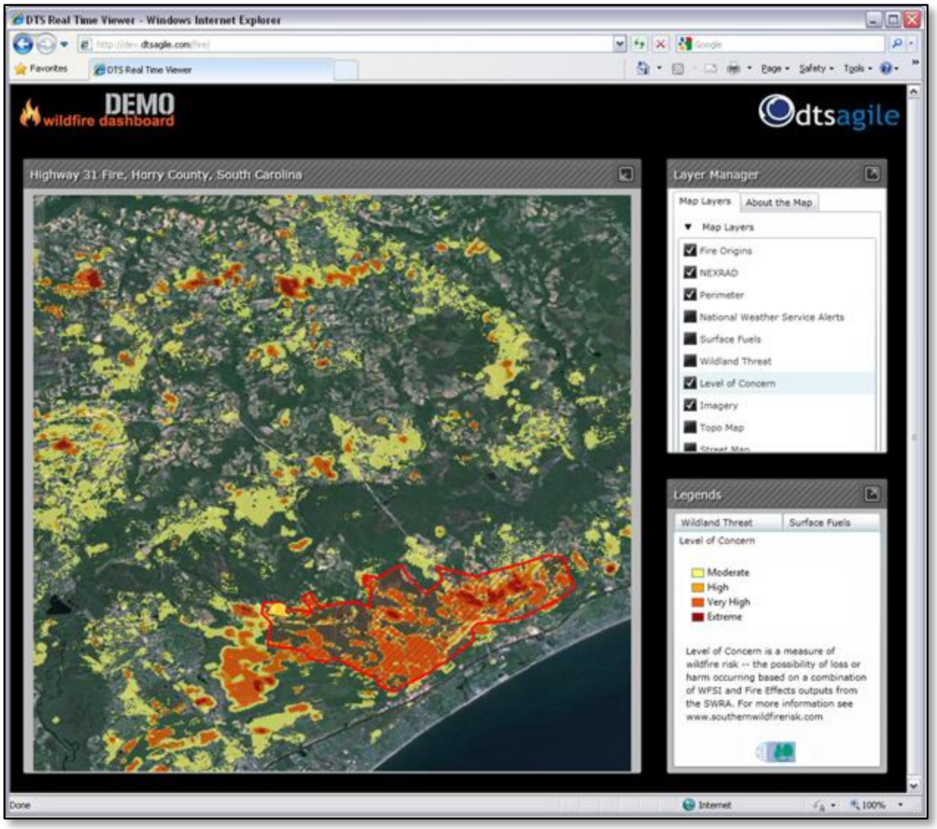


Figure 3. Integrating risk-assessment results with real-time data, such as fire perimeters, NEXRAD and NWS Alerts, provides greater utility for planners and responders.

Web-based access is critical to widespread use by professionals and the public with minimal GIS experience. Interactive mapping, with the ability to onscreen digitize or enter ZIP Codes to tailor results to specific areas of interest, is an important extension. The ability to easily generate summary reports and maps via the Web is central to using the data for planning purposes.

Extending Risk to Probable Impacts

The impacts and consequences of wildfire (or any catastrophic event) can be characterized as the following:

- *Economic*—loss of structures and property, damage to critical facilities and infrastructure, destruction of commercial forestland and agriculture cropland, etc.
- *Social*—damage to sensitive cultural archeological areas, disruption of employment, demographic displacement, loss of life, etc.
- *Environmental*—threatened and endangered species, sensitive wildlife and vegetation habitats, water sources, etc.

This article presents examples focused only on the economic consequences of wildfire by calculating “dollar exposure” based on the economic value of parcels. A full-featured model describes the social and environmental consequences, and prioritizing or weighting such consequences is a political and planning issue.

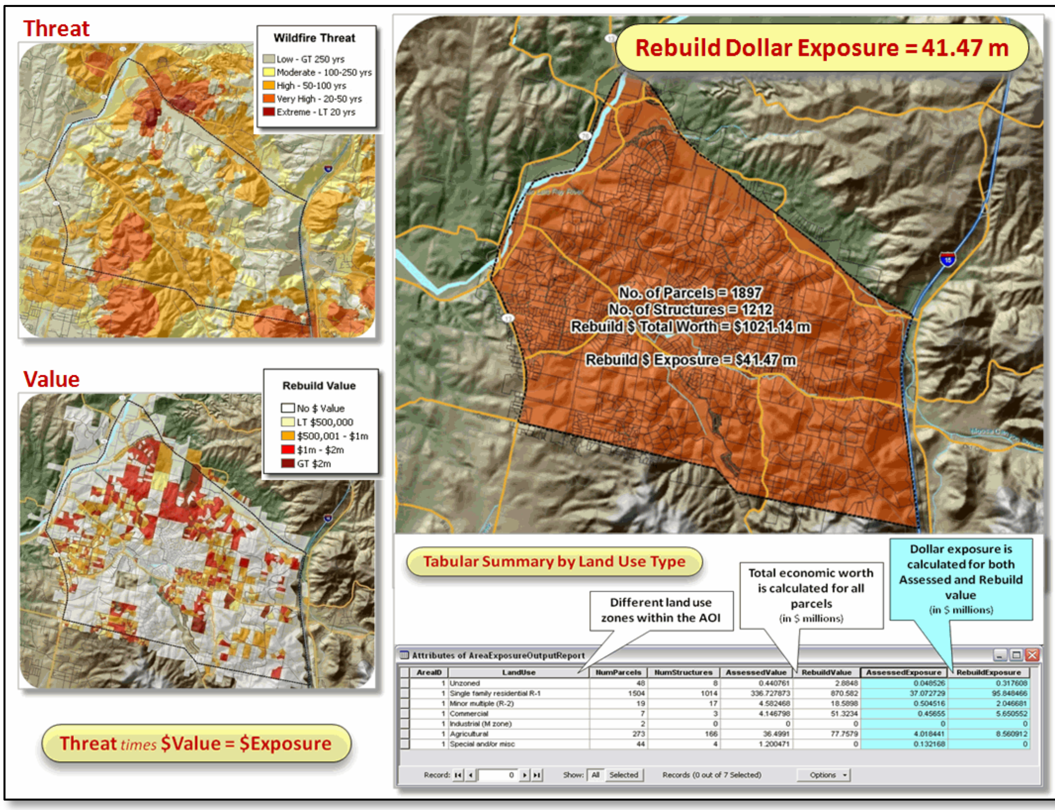
The model mimics the FEMA HAZUS software approach for calculating “dollar exposure” for earthquakes, hurricanes and floods. HAZUS is a risk-assessment tool used by government agencies (especially local governments) to analyze potential risk and perform loss estimation in support of mitigation and emergency-response planning.

Assessing Exposure and Damage

With wildfire risk data now becoming readily available in fire-prone areas, opportunities exist to use these data in concert with economic data to quantify potential impacts and losses. The extended wildfire risk model quantifies the economic impact of wildfire threat based on census or assessor data.

Assessor data provide the most detailed data on the value of ownership parcels in an area of interest and can be quantified in terms of "assessed" or "rebuild" dollar values. When assessor and parcel data aren't readily available, general census data can be used to calculate dollar exposure (i.e., median housing values).

The left side of Figure 4 shows maps of wildfire threat probabilities and the assessor's rebuild values for ownership parcels within a small area of San Diego County. The assessor's data provide detailed and up-to-date descriptions of the economic value for parcels and their structures.



AreaID	LandUse	NumParcels	NumStructures	AssessedValue	RebuildValue	AssessedExposure	RebuildExposure
1	Unzoned	48	8	0.440761	2.8848	0.048526	0.317608
1	Single family residential R-1	1504	1014	336.727873	870.582	37.072729	95.848466
1	Minor multiple (R-2)	19	17	4.582468	18.5898	0.504516	2.046681
1	Commercial	7	3	4.146798	51.3234	0.45655	5.650552
1	Industrial (M zone)	2	0	0	0	0	0
1	Agricultural	273	166	36.4991	77.7579	4.018441	8.560912
1	Special and/or misc	44	4	1.200471	0	0.132168	0

Figure 4. Economic exposure involves multiplying the probability of a wildfire (threat/hazard) times the value of each location (effects/consequences).

Specific data fields used in the model include improved parcel value, land-use zone, square footage for living space and additional square footage. The total square footage for all structures occupying a parcel is calculated by summing the two footage values. This total footage is multiplied by a user-defined rebuild value per square foot to calculate a total rebuild value for each parcel in the area.

Several problems with assessor data complicate their use. First, there are inconsistencies in data format and content, as each county tailors its database to fit internal needs. Similarly, timeliness is an issue due to a lack of standards for reporting period or established delay before making the data generally available. And accuracy can be a problem in the exactness and correctness of the data. This is particularly troublesome for large ownership parcels without coordinates for the exact location of structures within their borders.

The logic ingrained in the wildfire risk calculations involves four major steps:

1) Identify an area of interest from existing lists or by interactively digitizing a polygon and buffering it an appropriate distance.
2) Calculate the aggregated wildfire threat within the buffered area.
3) Calculate the total value of all structures for all parcels within the area of interest.
4) Calculate the “dollar exposure” by multiplying the aggregated threat times the total value: Dollar Exposure = Probability (value between 0.0 and 1.0) * Value (assessed and rebuild).

The model outputs for an area of interest include the total number of parcels, total number of structures, total assessed value for all structures, total rebuild value for all structures, and overall dollar exposure risk based on assessed and rebuild value. The output is displayed as thematic maps for any of the six output values.

To provide additional interpretation, a summary table of values is subtotaled by land-use zone. Each parcel is defined by its dominant land-use zone, and the model then loops through the parcels and keeps a running total of all the output values. Future enhancements to the model will overlay layers of critical facilities (e.g., roads, pipelines, sewer and water lines, hydrants, natural-gas pipelines, etc.) and report on the number of facilities to provide a more complete estimate of potential exposure.

Calculating ROI for Proposed Mitigation

An extended application of wildfire risk modeling is mitigation assessment for evaluating alternative management actions. This involves calculating the dollar exposure before and after proposed landscape fuel treatments, such as mechanical thinning or prescribed burning. Such treatments effect fuel composition, structure and loading, which are designed to change the behavior of a wildfire entering the treatment zone and thereby lessen the impact. The model tracks the change in fuels and the subsequent reduction in flame length, intensity and rate of spread, which translates into a change in the area’s wildfire threat values.

As shown in Figure 5, a return on investment (ROI) of mitigation can be calculated by the following equation: ROI_mitigation = ($Before - $After) / $Treatment. The smaller wildfire threat maps on the left depict the threat distribution before (top) and after (bottom) treating an area just south of the area of interest. In the example, the rebuild exposure was reduced $8 million—from $42 million before mitigation to $34 million after mitigation. Assuming a $100,000 treatment cost: ROI_mitigation = ($42m – $34m) / $100,000 = 80.0, which is a very favorable ROI.

Often large ratios are indicated, as total loss/destruction is implied for both *$Before* and *$After* assessments, and no fire-fighting intervention to moderate loss is considered. Also, wildfire behavior is simulated for “typical” conditions that might not reflect actual conditions. However, because assumptions for both *$Before* and *$After* are constant, the ROI ratio is stable.

The ROI ratio is useful in comparing alternative treatment areas and procedures. The ability to simulate different scenarios is paramount for effective budgeting and decision making. It’s important to note that periodic review is needed, however, because land-cover, land-use and assessor-map variables are temporally dynamic.

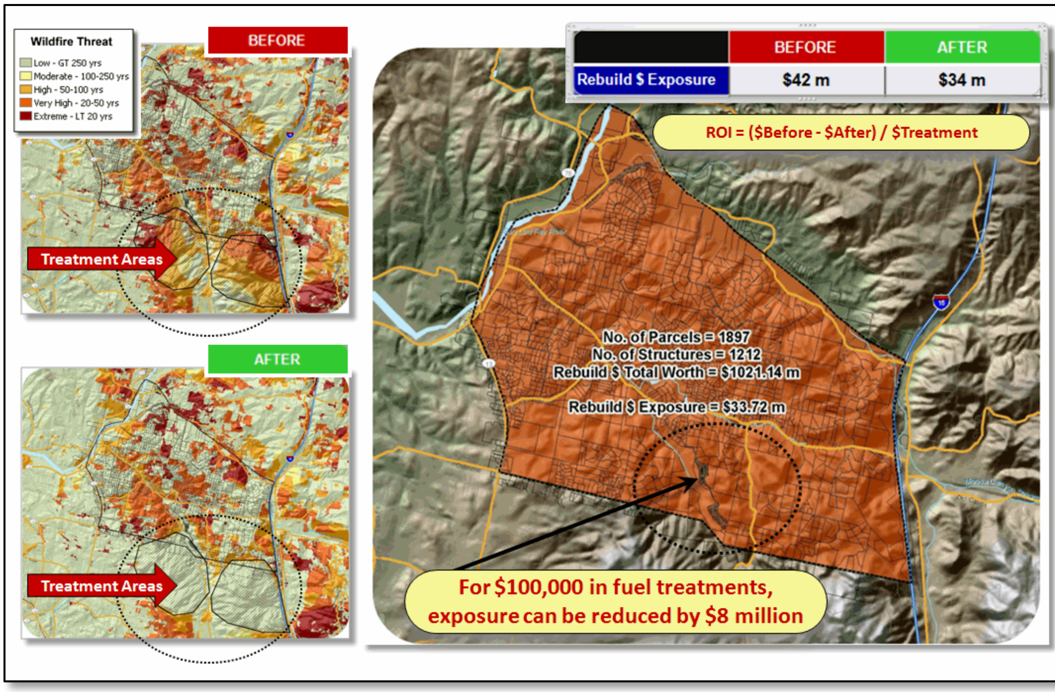


Figure 5. Rate of return of mitigation calculates the change in dollar exposure from before and after treatments designed to lower vegetation fuel loading.

Conclusion

Wildfire Risk Modeling has traditionally emphasized *Wildfire Threat* using tools developed by fire scientists and primarily used by fire suppression professionals. More recently modeling of *Wildfire Impacts* (Economic, Social and Environmental) is gaining interest, particularly by "non-traditional" parties and stakeholders concerned with policy, planning, mitigation and recovery as well as suppression. This article has described two significant extensions to contemporary wildfire risk modeling— 1) extending the relative risk scale (Low to High) to probability of fire occurrence (0 to 1.0 probability value) and intensity of burn, and 2) quantifying wildfire impacts and proposed mitigation efforts.

By coupling these technical advances with an interactive, web-based mapping environment a robust collaborative tool is provided for decision-making, funding allocation and communication with stakeholders and general public. The combined approach places a powerful risk assessment methodology for analyzing potential losses at the fingertips of an enlarged group of potential users concerned with wildfire risk and impacts.

Authors' Note: *for more information about Sanborn's Wildland Fire Risk Assessment System, visit www.sanborn.com/solutions/fire_management.asp. A slide set describing Wildfire Impact modeling is available at www.innovativegis.com/basis//present/GIS09_wildfire/GeoTec09_Wildfire.ppt.*

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