MAPPING WILDLAND FIRE RISK TO FLAMMABLE STRUCTURES FOR THE CONTERMINOUS UNITED STATES

James P. Menakis
Fire Effects Project, Fire Science Laboratory, Rocky Mountain Research Station, USDA Forest Service, P.O. Box 8089, Missoula, MT 59807

Jack Cohen and Larry Bradshaw
Fire Behavior Project, Fire Science Laboratory, Rocky Mountain Research Station, USDA Forest Service, P.O. Box 8089, Missoula, MT 59807

ABSTRACT

The threat of wildland fire burning flammable structures is a national issue. Every year the risk increases from the accumulation of wildland fuel and the building of flammable structures adjacent to wildlands. Flammable structures are structures that have a low resistance to ignition. Wildland fires are vegetation fires that start and burn mostly in unpopulated–non-developed areas. We defined and mapped the risk of wildland fire burning flammable structures for the conterminous United States. The map integrates three Geographic Information System (GIS) data layers: Housing Density, Potential Fire Exposure, and Extreme Fire Weather Potential. The Housing Density data layer classifies human habitation ranging from wildland to city in units of houses per hectare. The Potential Fire Exposure data layer combines vegetation into severe fire behavior classes that produce similar fire or heat intensity under extreme weather conditions. The Extreme Fire Weather Potential data layer classifies the average number of days per year when weather conditions were similar to those during past catastrophic fires that burned structures; this layer is based on temperature, relative humidity, and wind speed. From this analysis, we found a total of 7,621 km^2 are in the high-risk class of burning flammable structures for the conterminous United States, followed by 20,372 and 369,598 km^2 for the moderate- and low-risk classes, respectively. More than 92% of the area at risk of wildland fires to flammable structures occurs on non-federal lands. This fire risk classification provides managers a relative comparison of areas from high to low risk across the conterminous United States.

keywords: fire, flammable structures, risk, United States, wildland–urban interface.

Citation: Menakis, J.P., J. Cohen, and L. Bradshaw. 2003. Mapping wildland fire risk to flammable structures for the conterminous United States. Pages 41–49 *in* K.E.M. Galley, R.C. Klinger, and N.G. Sugihara (eds.). Proceedings of Fire Conference 2000: The First National Congress on Fire Ecology, Prevention, and Management. Miscellaneous Publication No. 13, Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

The threat of wildland fire to homes is a significant, growing concern for federal, state, and local land management agencies (Cohen 2000). Wildland fires destroyed 8,925 homes in the conterminous United States from 1985 to 1994 (USDA 2000). The growing human population and emigration to suburban and rural areas are increasing the concentration of houses adjacent to or embedded in wildlands, the area known as the wildland–urban interface. This demographic shift escalates the risk of private property losses from catastrophic wildfire (USDA 2000).

The combination of dry, windy weather, continuous fuels, and close proximity to residential developments creates a strong potential for wildland fires to burn homes. Wildland–urban interface fires usually start in wildland fuels. During dry, windy weather conditions and in areas with continuous fuels, a wildland fire can spread rapidly, exceeding fire-fighting capabilities (Cohen 2000, USDA 2000). In the wildland–urban interface, flames and lofted burning embers, called firebrands, may expose numerous homes to ignition sources (Cohen 2000).

Rapidly spreading wildland fires intermingled with flammable structures, specifically highly ignitable homes, can cause many homes to burn simultaneously (Cohen 2000). Cohen (2000) reported whole neighborhoods destroyed in a few hours by severe wildland–urban interface fires. For example, the 1990 Painted Cave fire in Santa Barbara, California, destroyed 479 homes in a few hours. The 1993 Laguna Hills fire in southern California destroyed 366 houses within 5 hours.

To address the scope of the wildland–urban interface fire problem, we mapped the risk of flammable structures being burned by wildland fire based on the integration of population density, fuels, and weather for the conterminous United States. We defined risk as the potential of wildland fire burning numerous houses in a single event. We assumed that all homes are highly ignitable or flammable, although recent research shows that the potential for residential ignition is usually determined by a home's exterior materials, design, and immediate surroundings, rather than strictly by wildland fire behavior (Cohen 2000). This map will provide land managers with a tool for prioritizing prevention activities and fuel-reduction treatments, and for working with communities on zoning issues, landscaping around the home, and reducing a home's flammability.

METHODS

To map the potential risk of wildland fire burning flammable structures, we integrated several spatial database layers in a Geographic Information System (GIS): Population Density, Potential Natural Vegetation Groups, Current Cover Types, and Extreme Fire Weather Potential. We classified the Population Density data layer into classes based on houses per hectare to create a Housing Density layer. A risk rating was assigned to each housing density class, based on the potential number of houses destroyed if a single catastrophic fire event were to occur. Low housing density was assigned a low risk rating because only a few houses would be destroyed, while high housing density was assigned a high risk rating because many houses could be destroyed. We combined Potential Natural Vegetation Groups and Current Cover Types data layers into severe fire behavior classes that produce similar fire or heat intensity. This layer is the Potential Fire Exposure layer. We created an Extreme Fire Weather Potential data layer by calculating the average number of days per year when weather conditions exceeded thresholds similar to days when past fires burned structures. Weather conditions include temperature, relative humidity, and wind. By combining the Housing Density, Potential Fire Exposure, and Extreme Fire Weather Potential layers, we produced a matrix used to assess risk of wildland fire burning flammable structures.

Housing Density

Housing Density classes were derived from the LandScan Global Population 1998 Database, developed at the Oak Ridge National Laboratory (Dobson et al. 2000). The database was derived from the best available census counts that were redistributed to spatial cells from probability coefficients related to road proximity, slope, land cover, and nighttime lights (Dobson et al. 2000). The LandScan population distribution represents an ambient population, which integrates diurnal movements and collective travel habits into a single measure (Dobson et al. 2000). This GIS layer was stored in 30 × 30-arc second raster layer in the Geographic Reference System.

Using the GIS, we clipped the LandScan Global Population data layer to the conterminous United States. The data layer was stored in a GIS pixel format (raster) using the Geographic Reference System, which has different area sizes associated with each pixel along a latitudinal gradient. For example, northern Montana had a pixel size of about 500 m^2, while southern Florida had a pixel size of about 850 m^2. To account for the different area sizes of each pixel, we created an area layer by calculating the square meters associated with each pixel. We then combined the clipped population density layer with the area layer and re-projected the combined layer into the Lambert Azimuthal Equal Area Projection, with a pixel size of 100 m^2. Next, we standardized population density values to population per 100 m^2, by first dividing the actual pixel size (100 m^2 in an equal-area projection) by the Geographic Reference System area pixel size (ranging from 500 to 850 m^2 from north to south) and then multiplying by the population density. Finally, we aggregated the population per 100 m^2 to 1-km pixel size layer by using a moving window and summing all 100-m^2 pixels in a 10 × 10 window.

To create a Housing Density layer, we reclassified the above population per km^2 layer into classes of housing density per hectare. To calculate housing density per hectare, we assumed that the average household contained 3 people per house. The low resolution of our data resulted in a loss of detail in housing densities at the suburban to rural level and below. Using a limited set of fine-scale (1:24,000 map scale) Census 2000 data (U.S. Census Bureau 2003*a*) at the census block level, we multiplied the housing density by a factor of 3 to increase the contrast between classes (see Figure 1). The Housing Density layer classes range from Very Low, $<$0.5 houses/ha ($<$0.20 houses/acre), to City, $>$24.7 houses/ha ($>$10 houses/acre) (Table 1). Housing Density classes (Table 1) are based on the potential number of houses destroyed if a single catastrophic fire event were to occur. A map of Housing Density classes is shown in Figure 2, which shows higher housing density surrounding cities and towns.

Potential Fire Exposure

The Potential Fire Exposure layer was derived from the Potential Natural Vegetation Groups version 2.0 and the Current Cover Types Layer version 1.0 developed by the USDA Forest Service Fire Effects Project (Schmidt et al. 2002). We combined these layers and grouped them into classes based on the maximum fire intensity that could occur in these vegetation types under extreme weather conditions (Table 2). We assumed that the fire intensity relates to the direct exposure of structures to flames (or heat intensity), and the size and amount of firebrands and the distance they are likely to travel. Three classes of Potential Fire Exposure were created (Figure 3): 1) High Exposure—continuous coniferous forest or dense shrub types (such as chaparral) that are extremely flammable and can produce high fire intensity and abundant firebrands under extreme weather conditions; 2) Moderate Exposure—hardwood forests that rarely have crown fires and low-growing shrub types that produce moderate fire intensity and few firebrands under extreme weather conditions; and 3) Low Exposure—mostly grasses, savannas and sparse shrub types that produce low fire intensity and few or no firebrands under extreme weather conditions. Most high exposure occurs in the western U.S. (Figure 3).

Extreme Fire Weather Potential

We created the Extreme Fire Weather Potential layer based on 16 years of hourly weather observations from over 500 weather stations throughout the conter-

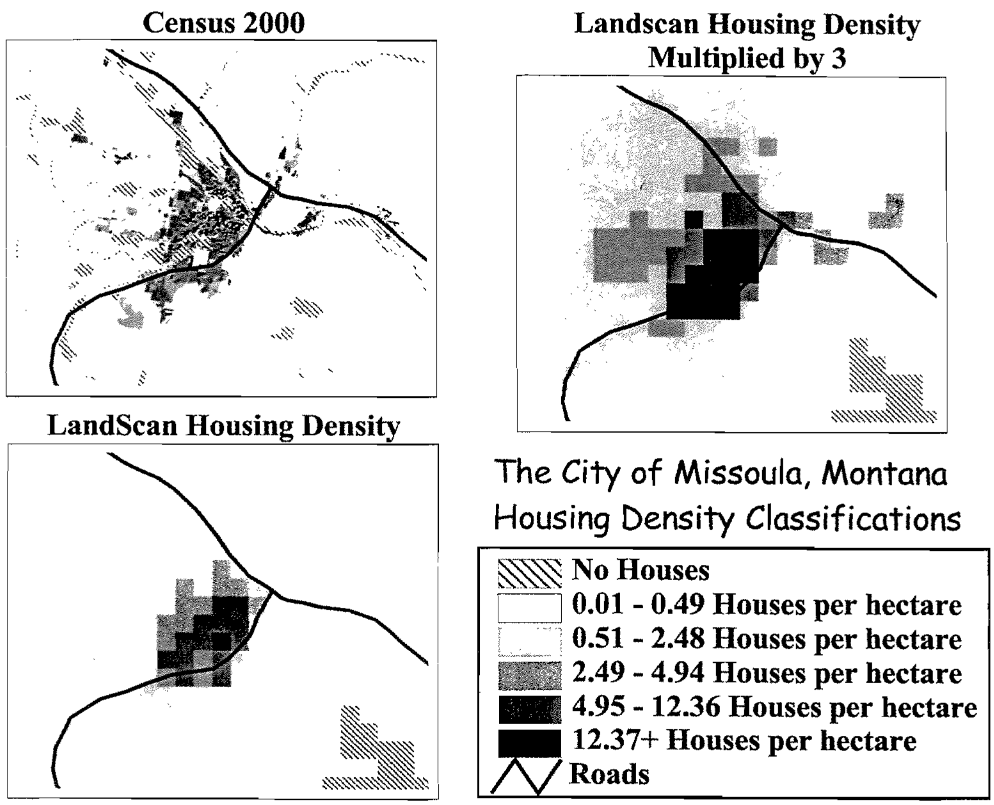

Fig. 1. Census 2000 housing density (pixel size 30 m²) compared with LandScan housing density classes (pixel size 1 km²) for Missoula, Montana. LandScan housing density classes were multiplied by 3 to better match the Census 2000 data.

minous United States. For each weather station, we calculated the average number of days per year when weather conditions met or exceeded a minimum weather threshold. The minimum weather threshold was based on an analysis of the weather conditions during recent wildland fire events that burned flammable structures (Table 3). These thresholds consisted of winds >32.2 km/h (20 miles/h), temperatures >4.4 °C (40 °F), and humidity <20% for the western U.S. and <40% for the eastern U.S. The east–west division was based on a combination of Bailey's ecoregions (Bailey et al. 1994) and 4th Code Hydrologic Units (Seaber et al. 1987) and is shown in Figure 4. All weather thresholds had to occur in a single hourly observation for a day to be tallied, and only one tally was allowed for each day.

To make a continuous raster layer from the tallied threshold weather station points, we used a standard inverse distance weighted interpolation algorithm in the GIS. We then used a weighted smoothing algorithm across a 3 × 3 window to remove the abrupt edges in the interpolated raster layer. Finally, we reclassified the weather thresholds into four classes: 1) Low—0 to 3 average days per year above weather threshold, 2) Moderate—4 to 9 average days per year above weather threshold, 3) High—10 to 30 average days per year above weather threshold, and 4) Extreme—>30 average days per year above weather threshold. A map of Extreme Fire Weather Potential is shown in Figure 4, which shows most Extreme Fire Weather Potentials occurring in the southwestern U.S.

Table 1. Housing Density classes in the conterminous United States.

Class	Houses per hectare	Houses per acre
None	0	0
Very low	0.01–0.49	0.01–0.20
Low	0.50–2.48	0.21–1.0
Moderate	2.49–4.94	1.01–2.0
High	4.95–12.36	2.01–5.0
High/City (very high)	12.37–24.71	5.01–10.0
City	24.72+	10.01+

Matrix

To assign a risk class of burning flammable structures during a wildland fire, we combined Housing Density, Potential Fire Exposure, and Extreme Fire Weather Potential data layers into a matrix. To each combination of these layers, we assigned a risk class. The risk rating was based on the lowest class of the three layers, so low housing density was assigned low risk even where potential fire exposure and extreme fire weather potential were high. For example, areas with low housing density with low fire exposure and extreme fire weather potential were assigned a low risk rating, while areas of high housing density with high fire exposure and extreme fire weather were assigned a high risk.

To account for firebrands (during severe fire events) that could travel over 1 to 2 km into developed areas adjacent to high fire exposure vegetation, we cre-

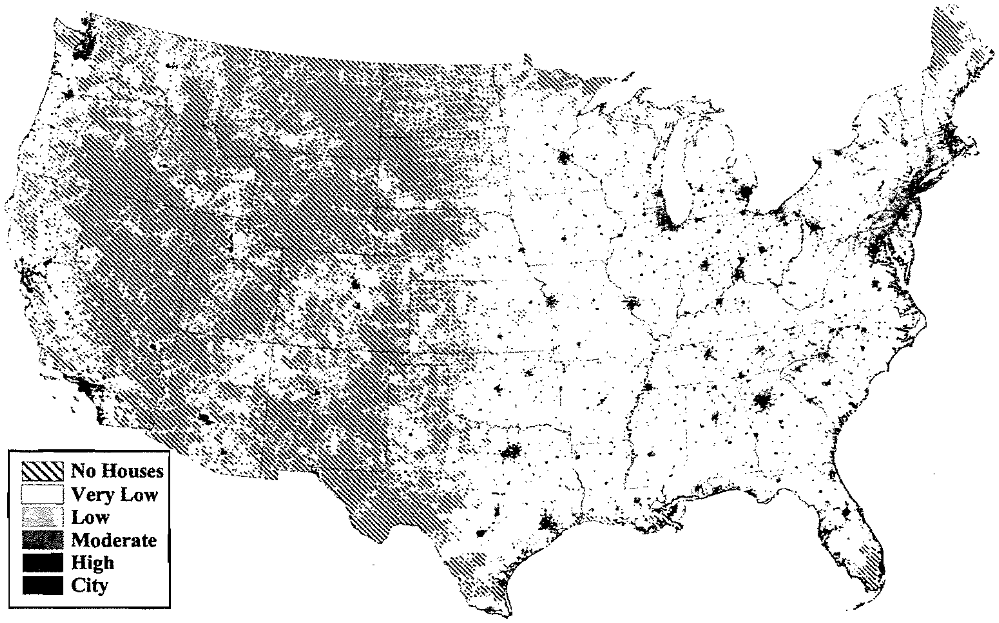

Fig. 2. Housing density map used for creation of a map predicting risk from wildland fires to flammable structures in the conterminous United States. See Table 1 for explanation of housing density classes.

Table 2. Potential Fire Exposure assignment based on the combination of Current Cover Type and Potential Natural Vegetation Group data layers (Schmidt et al. 2002) for the conterminous United States. Each of the 63 Potential Natural Vegetation Type Group classes was summarized by a general description.

Current cover type	Potential natural vegetation groups—general description	Potential fire exposure	Area (km²)
Agriculture	All	Agriculture	2,061,783
Grassland	All	Low	859,672
Wetlands	All	Moderate	25,455
Desert shrub	All	Low	523,627
Other shrub	Grasses, hardwoods, and bogs	Low	392,900
Other shrub	Juniper, pinyon, sagebrush, shrub steppe, and hardwood–conifer mix	Moderate	433,230
Other shrub	Conifer, chaparral, and mesquite	High	63,295
Other shrub	Alpine meadows and barren	Barren–alpine	754
Oak–pine	All	Moderate	195,484
Oak–hickory	All	Low	578,629
Oak–gum-cypress	All	Moderate	121,018
Elm–ash–cottonwood	All	Low	39,637
Maple–beech–birch	All	Low	297,837
Aspen–birch	All	Low	108,628
Western hardwoods	All	Low	46,047
White–red–jack pine	All	High	76,282
Spruce–fir (East[a])	All	High	68,554
Longleaf–slash pine	All	High	85,695
Loblolly–shortleaf	Oak–hickory–pine	Moderate	172,512
Loblolly–shortleaf	All others	High	63,362
Ponderosa pine	All	High	234,349
Douglas–fir	All	High	161,371
Larch	All	Moderate	11,304
Western white pine	All	High	8,366
Lodgepole pine	All	High	122,462
Hemlock–Sitka spruce	All	High	17,708
Fir–spruce	All	High	101,069
Redwood	All	Low	5,823
Pinyon–juniper	All	High	220,996
Alpine tundra	All	Barren–alpine	15,509
Barren	All	Barren–alpine	146,063
Water	All	Water	95,263
Urban–development–agriculture	Grasses, hardwoods, bogs	Low	243,219
Urban–development–agriculture	Juniper, pinyon, sagebrush, shrub steppe, hardwood–conifer mix	Moderate	131,438
Urban–development–agriculture	Conifer, chaparral, mesquite	High	48,453

[a] Eastern United States.

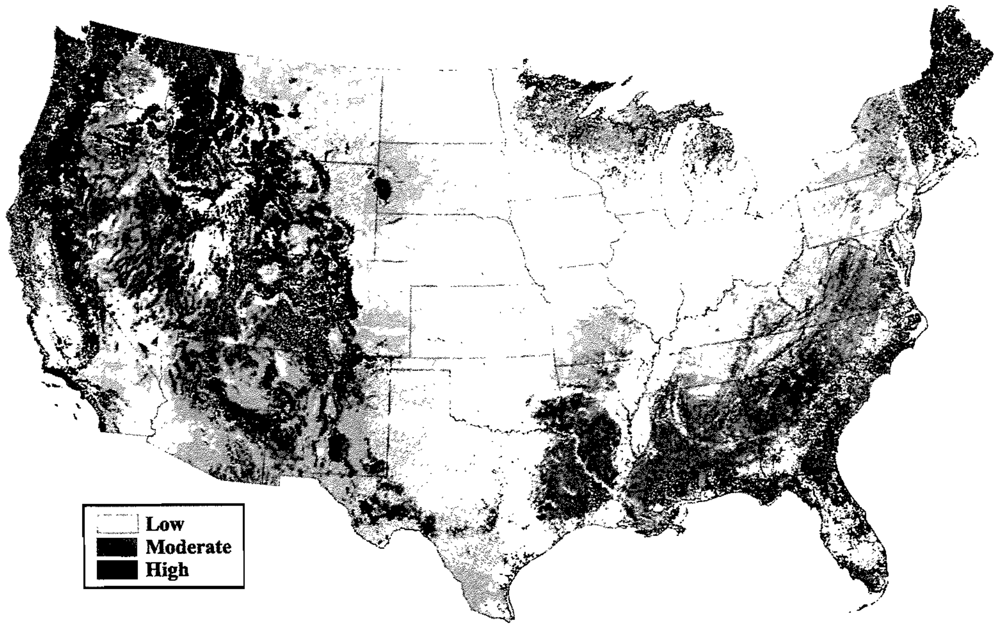

Fig. 3. Potential fire exposure map used for creation of a map predicting risk from wildland fires to flammable structures in the conterminous United States. See text for explanation of fire exposure risk classes.

ated two additional Housing Density Classes by creating buffer areas around areas of high housing densities. Using the GIS, we created a 2-km buffer around the Moderate Housing Density class (2.5–4.9 houses per hectare). Where this buffer overlapped the Housing Density classes Low, Very Low, or None, we reassigned the Housing Density Layer to the Moderate Buffer class. We also created a 2-km buffer around Housing Density classes High (5.0–12.4 houses/ha) and Very High (12.4–24.7 houses/ha). Where this buffer overlapped the Housing Density classes Low, Very Low, or None, we reassigned the Housing Density Layer to the High–Very High Buffer class. We assigned the High–Very High Buffer class to the areas where the High–Very High Buffer class and the Moderate Buffer class overlapped.

Next, we assigned risk classes to the new buffer classes. The complete matrix is shown in Table 4. We then loaded the matrix assignments in the GIS to create the final data layer.

Table 3. Wildland fires in the conterminous United States that destroyed many homes from 1985 to 1993. Most houses that were destroyed were lost in a single event.

Fire (state)	Date	Houses burned
Palm Coast (FL)	17 May 1985	99
Forty-niner (CA)	11 Sep 1988	148
Black Tiger (CO)	08 Jul 1989	44
Dude (AZ)	25 Jun 1990	53
Painted Cave (CA)	27 Jun 1990	479
Stephen Bridge (MI)	08 May 1990	76
Spokane Fire (WA)	16 Oct 1991	114
Oakland "Tunnel" (CA)	21 Oct 1991	2,103
Laguna Hills/Malibu (CA)	27 Oct 1993	350–366

RESULTS

The final map of Wildland Fire Risk to Flammable Structures is shown in Figure 5 for the conterminous United States. A total of 7,621 km^2 are in the High risk class for the conterminous United States, followed by 20,372 and 369,598 km^2 for the Moderate and Low risk classes, respectively. The total area for each risk class by federal land ownership is shown in Table 5. More than 92% of the area at risk of wildland fires to flammable structures occurs on non-federal lands (Table 5).

The states with the most area in the High risk class are shown in Table 6. California had the most area in the High risk class with 3,222 km^2 (42% of the total area in the conterminous United States). Massachusetts, a state not known to have large fires, was second with 829 km^2 (11% of the total area) followed by three other western states: Utah, Colorado, and New Mexico. The reason Massachusetts appears in this class is perhaps because the state has a risk problem as defined in this paper, plus a great deal of fragmentation, which limits fire size. The 11 western states (Washington, Oregon, California, Idaho, Nevada, Utah, Arizona, Montana, Wyoming, Colorado, and New Mexico) contain 5,156 km^2 (68%) in the High risk class, followed by 6,981 km^2 (34%) in the Moderate risk class, and 64,416 km^2 (17%) in the Low risk class.

The results of this risk analysis are only as reliable as the data that form its basis. The methods used to re-project LandScan Global Population Database were accurate to 99.9%, when comparing total population densities in the original LandScan Database to the final projected and aggregated population densities for three geographic areas: Montana, a test strip from northern Illinois to east Texas, and the conterminous United

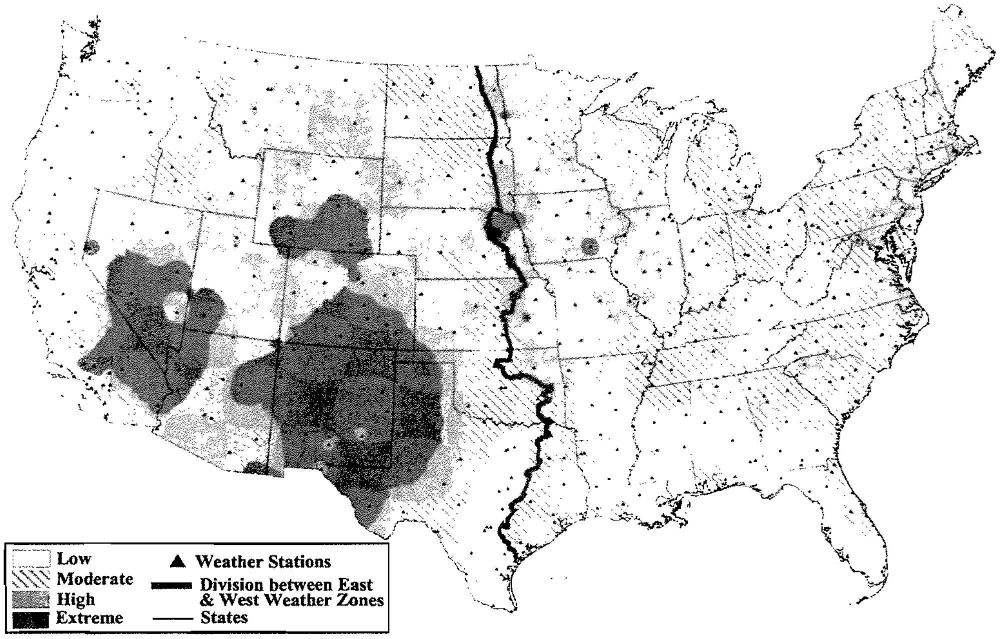

Fig. 4. Extreme fire weather potential map used for creation of a map predicting risk from wildland fires to flammable structures in the conterminous United States. See text for explanation of weather threshold classes.

Table 4. Matrix used to assign wildfire risk of burning flammable structure classes based on the combination of Housing Density Potential Fire Exposure classes and Extreme Fire Weather classes overlaid in the Geographic Information System.

Risk class	Housing density class	Potential fire exposure	Extreme fire weather potential
No Houses	No Houses	Low, Moderate, High	Low, Moderate, High, Extreme
Very Low	Very Low	Low, Moderate, High	Low, Moderate, High, Extreme
Low	Moderate buffer	Low	Low, Moderate, High, Extreme
		Moderate	Low, Moderate, High
		High	Low, Moderate
	High–Very high buffer	Low	Low, Moderate, High, Extreme
		Moderate	Low, Moderate, High
		High	Low, Moderate
	Low	Low	Low, Moderate, High, Extreme
		Moderate	Low, Moderate, High
		High	Low, Moderate
	Moderate	Low	Low, Moderate, High, Extreme
		Moderate	Low, Moderate
		High	Low
	High–Very high	Low	Low, Moderate, High, Extreme
		Moderate	Low
		High	Low
Moderate	Moderate buffer	Moderate	Extreme
		High	High, Extreme
	High–Very high buffer	Moderate	Extreme
	Low	Moderate	Extreme
		High	High, Extreme
	Moderate	Moderate	High, Extreme
		High	Moderate
	High–Very high	Moderate	Moderate, High
High	High–Very high buffer	High	High, Extreme
	Moderate	High	High, Extreme
	High–Very high	Moderate	Extreme
		High	Moderate, High, Extreme
Non-vegetation	No houses–Moderate	Non-vegetation	All
Agriculture	No houses–Moderate	Agriculture	All
Water	All	Water	All
City	Very high	Non-vegetation, agriculture	All
	City	Low, moderate, high, non-vegetation, agriculture	All

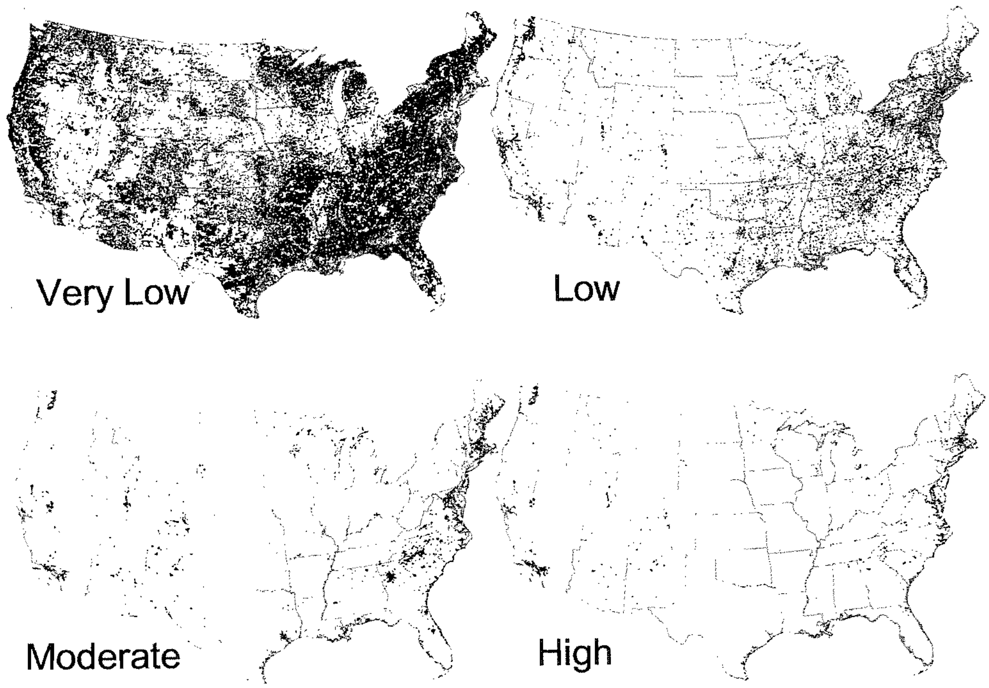

Fig. 5. Maps for wildland fire risk classes to flammable structures in the conterminous United States. See text for explanation of fire risk classes.

States and surrounding land area. Visual comparisons using different classification schemes confirmed that the projection and aggregation procedure maintained the integrity of the data.

In this analysis, we assumed 3 people per household when calculating housing density from population density. Further research reveals this estimate might be high when looking at one county. The U.S. Census Bureau reported that Missoula County has a total population of 78,687 and 33,466 housing units (U.S. Census Bureau 2003*b*) for 1990. Based on these numbers, Missoula County has about 2.35 people per household, instead of the 3 people per household we used in this analysis. Without further research, it would be difficult to extrapolate this number across the nation.

The threshold used to assign Extreme Fire Weather Potential was compared to nine fires that had burned structures (Table 3). For each of these fires, the weather thresholds were compared to the weather at the time of the fire based on data from the closest weather station. The 1990 Stephen Bridge fire in Michigan was the only fire to fall outside the weather thresholds. Further review of the reports for the Stephen Bridge fire showed that it was within the weather thresholds at the fire site but was outside the weather threshold at the nearest weather station. The reason for the difference could be that the fire was in the interior of Michigan, while the weather station was along the coast of Lake Michigan.

DISCUSSION

The classes used in this analysis to assign risk to flammable structures from wildland fire were designed to target areas where a single fire event could destroy many homes. These single events are driven by a combination of extreme fire weather occurrence, high fire intensity, and high density of homes. Areas with moderate to high populations but with low to very low risk to flammable structures were missing one or more of these factors. Though risk in these areas is low, it does not mean a single fire event could not endanger structures. In 2000, wildland fire burned over 70 structures in western Montana areas classified in the wildland fire risk map as low or very low. These areas are classified as low because western Montana averages <10 days

Table 5. Wildland fire risk to flammable structures in the conterminous United States by land ownership.

	Federal lands		Non-federal lands		
Risk class	Area (km²)	Percent ownership	Area (km²)	Percent ownership	Total
Low	24,435	7	345,163	93	369,598
Moderate	4,656	23	15,716	77	20,372
High	1,717	23	5,904	77	7,621
Total	30,808	8	366,783	92	397,591

Table 6. States in the conterminous United States with the largest area of high wildland fire risk to flammable structures.

State	Area (km²)	Percent total area[a]
California	3,222	42
Massachusetts	829	11
Utah	521	7
Colorado	481	6
New Mexico	348	5

[a] Percent of total area in the High Risk class for the conterminous United States.

per year of extreme fire weather, compared to parts of New Mexico that average from 27 days to 90 days per year. This fire risk classification thus provides a relative comparison of areas from high to low risk across the conterminous United States.

The Wildland Fire Risk to Flammable Structures classification describe here is a coarse-scale analysis and is not intended to be summarized at a scale finer than state level. The methods used to develop this layer could be applied at finer scales with better data. The data layers used to develop this layer were the best data layers available at the time. Each of the data layers has anomalies associated with it that may be compounded when layers are combined. By classifying general classes of low, moderate, and high, we smoothed over some of these anomalies and present information in a relative fashion. The anomaly associated with the Population Density Layer developed by the Oak Ridge Laboratory involved their mapping ambient population (Dobson et al. 2000). This methodology spreads the population counts across many road corridors because it integrates diurnal movements and collective travel habits. When comparing the reclassification of housing density between the LandScan 2000 and Census 2000 data layers, we found that the housing density in LandScan was lower for areas in and around cities than it was for the census data (Figure 1). We also found that LandScan population densities were spread over many pixels along road corridors where there were no houses. Because of our concerns for mapping housing density in and around cities (where the greatest loss of houses can occur from a single event), we used a multiplication factor of 3 to adjust our breaks of housing density, which better visually matched the finer scale data from the 2000 Census. The housing density layers we developed therefore address the problem of the wildland–urban fire interface at a coarse scale.

The original vegetation layers we used, Current Cover Types version 1.0 and Potential Natural Vegetation Types version 2.0, had some anomalies in their classification schemes that required resolution to produce the Potential Fire Exposure classes. The cover type layer maps the dominant or modal overstory species in a pixel. For example, a Ponderosa Pine Cover Type could be composed of 40% ponderosa pine (*Pinus ponderosa*), 30% Douglas-fir (*Pseudotsuga menziesii*), and 30% grasses and shrubs. This becomes a problem when mapping Potential Fire Exposure classes in mixed types of hardwoods and pines. We addressed the problem for each location where it was identified. For example, where the Loblolly–Shortleaf Cover Type overlays the Oak–Hickory–Pine Potential Natural Vegetation Type (which runs through Atlanta, Georgia), we dropped the Potential Fire Exposure Class from high to moderate because of the mixture of hardwoods with pines.

The anomalies associated with the Extreme Fire Weather Potential data layer relate to the dividing line separating the east and west thresholds. This line was based on expert opinion. The high weather threshold occurring in the northern Midwest (Figure 4) could result from the placement of this dividing line between the thresholds. We expected the Midwest to have a moderate weather threshold. Further research might reveal a need to move this line and/or create a weather transition zone.

This wildland fire risk analysis assumes that all homes are highly ignitable. In reality, ignitability is variable. Not all homes in the wildland–urban interface are highly ignitable. Ignitability can be reduced, but treating the fuels around a flammable house will not necessarily prevent it from burning during a wildland fire. Recent research has shown that a home's exterior design and materials, and its surroundings within 30 to 60 m (100 to 200 feet) (the "home ignition zone") determine ignition risks associated with wildland fires (Cohen 2000). Modifications within the home ignition zone can significantly reduce the risk of structure ignition from a wildland fire. Thus, the risk of home ignition and loss to fire can be largely unrelated to fire behavior in the surrounding wildlands. Our wildland fire risk analysis does not consider the individual home ignition zone characteristics. This implies that the wildland fire risk map does not assess the actual risk of home fire losses, but rather assesses the potential for homes to be exposed and destroyed by wildland fire.

ACKNOWLEDGMENTS

We appreciate the help and support received from Amy Rollins, Denny Simmerman, and Cam Johnston from the Fire Effects Project, Fire Science Laboratory, Rocky Mountain Research Station, USDA Forest Service, in developing this document. We also thank Neil Sampson from the Sampson Group and Lowell Lewis from Forest Health Technology Enterprise Team in Fort Collins, Colorado, for their early contributions with the LandScan Global Population 1998 Database. Lastly, we thank Jane Smith and Kirsten Schmidt from the Fire Effects Project, Fire Science Laboratory, Rocky Mountain Research Station, USDA Forest Service, for their editorial review of this paper.

LITERATURE CITED

Bailey, R.G., P.E. Avers, T. King, and W.H. McNab (eds.). 1994. Ecoregions and subregions of the United States [map]. Scale 1:750,000. With supplementary table of map unit descriptions, compiled and edited by W.H. McNab and R.G. Bailey. U.S. Geological Survey, Washington, D.C.

Cohen, J.D. 2000. Preventing disaster: home ignitability in the wildland–urban interface. Journal of Forestry 98(3):15–21.

Dobson, J.E., E.A. Bright, P.R. Coleman, R.C. Durfee, and B.A. Worley. 2000. LandScan: a global population database for estimating populations at risk. Photogrammetric Engineering & Remote Sensing 66:849–857.

Schmidt, K.M., J.P. Menakis, C.C. Hardy, W.J. Hann, and D.L. Bunnell. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. General Technical Report RMRS-GTR-87, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Seaber, P.R., F.P. Kapinos, and G.L. Knapp. 1987. Hydrologic unit maps. Water Supply Paper 2294, U.S. Geological Survey, Denver, CO.

U.S. Census Bureau. 2003*a*. United States Census 2000. http://www.census.gov/main/www/cen2000.html

U.S. Census Bureau. 2003*b*. American FactFinder: tables: general characteristics: population and housing: Missoula County, Montana. http://factfinder.census.gov/servlet/BasicFactsServlet

USDA. 2000. Protecting people and sustaining resources in fire-adapted ecosystems: a cohesive strategy. The Forest Service Management Response to the General Accounting Office Report GAO/RCED-99-65, October 13, 2000. http://www.fs.fed.us/publications/2000/cohesive_strategy10132000.pdf