Wildfire Hazard Assessment for Community Land Use Planning: A Case Study in Chelan County, WA

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INTRODUCTION

Federal wildland fire agencies are increasingly reaching across jurisdictional boundaries to their state, county, and local partners to better manage the unwanted effects of wildland fire, guided, in part, by the National Cohesive Wildfire Strategy. This collaborative and inclusive fire management strategy includes efforts to promote fire adapted communities through improved land use planning via a program called Community Planning Assistance for Wildfire (CPAW, http://planningforwildfire.org/). CPAW provides communities with professional assistance from land use planners, foresters, economists, and wildfire modelers to integrate wildfire mitigation into the development planning process. Communities apply to participate and implementation of recommendations is under the authority of local jurisdictions. We report on the collaborative CPAW process between federal research and management with county and local representatives in Chelan County, WA, to map wildfire hazard as the basis for identifying areas where existing and proposed development may require regulation that safeguards life and property.

Together, maps of wildfire hazard, wildland-urban interface (WUI), and mitigation difficulty provide spatial context to delineate land use planning regulations, like requirements for fire-resistant building materials or defensible space. We summarized burn probability outputs from fire behavior models to quantify wildland fire hazard at two spatial scales, as relevant to Chelan County community wildfire risk management interests. We emphasize the importance of an iterative and collaborative process of modifying methods according to local input, and we highlight the value of discussions about the mapping process in bringing diverse stakeholders together to fortify relationships around community wildfire risk reduction.

CHARACTERIZING WILDFIRE HAZARD

Wildfire hazard is a measure of the likelihood that an area will burn and the likely intensity of the burn, given that a fire occurs. For this community assessment in Chelan County, we used established wildfire risk assessment methodology (Scott et al. 2013) to develop wildfire hazard maps for two scales: “landscape” and “local.”

Landscape-level Wildfire Hazard

We integrated wildfire likelihood and intensity information from 120-m cell size fire behavior modeling outputs from the Large Fire Simulator (FSim; Finney et al. 2011), originally produced for a wildfire risk assessment for OR and WA (Stratton 2017), to characterize “landscape” wildfire hazard, or the hazard due to large fires. Landscape level fire likelihood (i.e. burn probability), is the FSim-modeled annual likelihood that a wildfire will burn a given point or area. FSim can apportion burn probability into wildfire intensity levels and produce estimates of the probability of a certain flame length, given a fire

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burns a pixel. Conditional flame length is the weighted average of all flame length probabilities that FSim simulated for each 120-m pixel. We multiplied the burn probability by the conditional flame length raster to produce the landscape wildfire hazard raster.

To summarize the spatial metrics of likelihood, intensity and hazard for the "landscape" analysis, we chose subwatersheds ("HUC12"; Watershed Boundary Dataset, USDA-NRCS et al. 2017) as the polygon summary unit within which we assigned the mean of all pixel values. The HUC12 unit is based on the areal extent of surface water draining to a point, is commonly used to summarize landscape attributes, and is "administratively-neutral", as it is not related to administrative or political boundaries. Using a biophysically-based summary unit is important because fire spread is inherently dynamic and fire moves across landscapes without respect to political boundaries. Additionally, summarizing pixel-based information to polygons allows for broad-scale patterns to emerge that may not be immediately obvious in the raw pixel datasets. We classified the mean landscape wildfire hazard into three classes (Moderate, High, and Very High) based on quantiles in the distribution of values within the analysis area (fig. 1A). We did not include a "Low" wildfire hazard category, as every pixel on the landscape is within 1.5 miles of burnable vegetation, and as such, we assumed that everywhere in the county is potentially exposed to fire branding.

Local-level Wildfire Hazard

While the "landscape"-level hazard assessment characterizes the large fires which account for the majority of area burned, we also represented local fire events, which can have a devastating impact on a community. Chelan County experienced such an event in 2015 when the Sleepy Hollow fire destroyed 29 homes and several commercial buildings within the city of Wenatchee. At our hazard mapping workshop in 2017, this event was still fresh in the minds of those who experienced it, so community stakeholders wanted to capture the potential for what is often referred to as a "problem fire."

To represent wildfire hazard for a "problem fire" situation, we used the Minimum Travel Time (MTT) option within FlamMap 5.0 (Finney 2006) to generate burn probabilities and flame length probabilities under 97th percentile weather conditions. Performing a custom simulation for the county also allowed us to

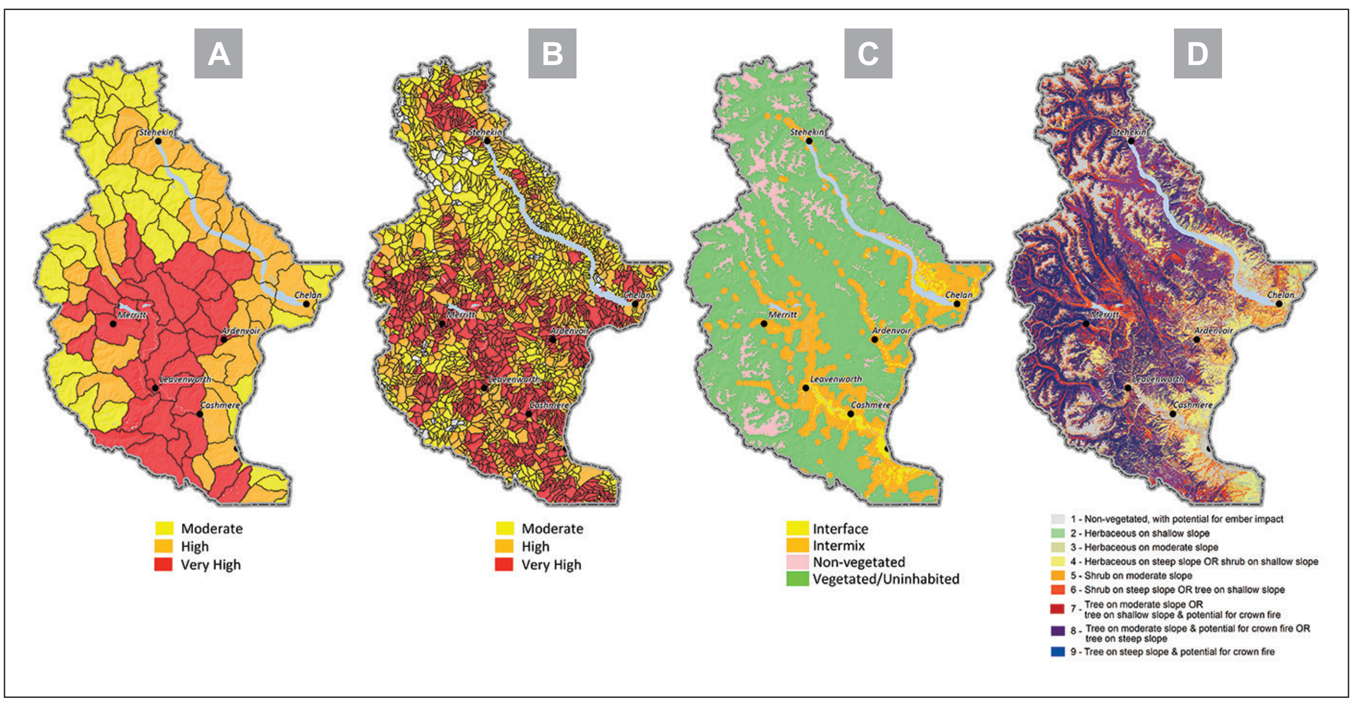

Figure 1—Maps needed to provide spatial context to Chelan County CPAW land use planning recommendations: (A) "Landscape" wildfire hazard; (B) "Local" wildfire hazard; (C) Wildland urban interface; (D) Mitigation difficulty.

tailor landscape and fuels simulation inputs to reflect local conditions at a finer spatial resolution. We used the same 30-m resolution landscape files (including all topography and fuels spatial data necessary to parameterize FlamMap 5.0; LANDFIRE 2014) that were the basis for the "landscape" assessment, but we modified them to represent local conditions. We made the following changes to the input fuel model layers to reflect input from subject matter experts (SMEs):

- Past fires and fuel treatments—we devised rulesets in collaboration with SMEs to change the fuel model, canopy height, canopy cover, and canopy bulk density layers to represent how the landscape changed as a result of these disturbances. Rules depended on factors such as time since disturbance, existing fuel conditions, elevation, land ownership type, and treatment type.
- Ravines—heavy fuel commonly accumulates in ravines adjacent to homes and orchards due to landowners discarding landscaping debris. SMEs reported that these fuels contributed to extreme fire behavior that caused structure loss during the Sleepy Hollow fire. We used a derivative of a digital elevation model and other GIS techniques to identify ravines near homes and orchards, and we changed the fuel model in those areas to a slash/blowdown model that produces high intensity fire behavior.
- Orchards—in Chelan County, SMEs reported that orchards are typically irrigated and thus do not contribute to fire behavior. We obtained an agriculture GIS layer from the county and represented orchards as non-burnable fuels.

We initialized the MTT module within FlamMap5.0 with 54,044 fire ignitions whose locations were random, but informed by locations where wildfires have occurred during the period of 1992 through 2015 (Short 2017). Using FlamMap5.0 outputs, we created a set of six flame length probability rasters (one for each flame length class: 0-2 ft , 2-4 ft, 4-6 ft, 6-8 ft, 8-12 ft, >12 ft), and calculated a conditional flame length raster as the sum-product of the probability and the flame length across all flame length classes. Finally, we calculated the final local wildfire hazard raster as the product of the burn probability and conditional flame length rasters.

To summarize the spatial metrics of likelihood, intensity and hazard for the "landscape" analysis, we chose National Hydrography Dataset Plus V2 catchments (USEPA and USGS 2012). Catchments are local level drainage areas and typically subdivide HUC12 watersheds into smaller polygon units. Following the same approach used in the "landscape" level analysis, we classified the mean "local" wildfire hazard into three classes (Moderate, High, and Very High) based on quantiles in the distribution of values within the analysis area (fig. 1B).

MAPPING WILDLAND URBAN INTERFACE

We mapped categories of structure density integrated with wildland vegetation to characterize where structures exist within or adjacent to burnable wildland vegetation in Chelan County. Though we generally followed methods that mimic Federal Register Wildland Urban Interface definitions (USDA and USDI 2001) as adapted by Martinuzzi et al. 2015, we customized our mapping to include representation of structures in rural areas.

Conventionally, WUI is mapped using census data for population density information and census blocks as the summary unit. In Chelan County, the size of the census blocks range from less than an acre to over 265,000 acres and though structures may exist in the larger blocks, the value attributed to the entire block will be a "low structure density" class, with no spatial delineation as to where the structures exist within the larger unit. Since the county has accurate and up-to-date address point data for all structures, we were able to use these points, instead of census data, to represent structures for our WUI mapping effort. We input the point data into a Kernel Density tool (ESRI 2015) to create a 30-m resolution raster surface of structure density, which we then sliced into the ranges of values specified in the Federal Register definition (structures per km2): < 6.18, 6.18 – 49.42, 49.42 – 741.32, and > 741.32, to represent Very Low, Low, Medium, and High structure density, respectively.

To map the vegetation conditions as specified in the WUI definition, we assumed wildland vegetation as anything that is classed with a "burnable" fuel model in the same fuel model raster data that we used as input to our fire behavior modeling. We used Focal Statistics (ESRI 2015) to create a raster surface in which 30-m pixel values represent the percentage of burnable fuel within a 40 ac window, which we then classified into two levels: 50 percent and 75 percent vegetation. Finally, we combined the structure density and vegetation rasters so that the final WUI map included the following categories: Interface, Intermix, Non-WUI Vegetated, and Non-Vegetated or Agriculture (fig. 1C). One modification we made to the rules outlined in Martinuzzi et al. 2015 was to include the "Vegetated Very Low Density" category (structure density < 6.18 structures/km^2 and wildland vegetation >50%) in the Intermix category. This decision reflects our intent to include isolated structures in rural areas as WUI.

MAPPING MITIGATION DIFFICULTY

As a complement to the "landscape" and "local" wildfire hazard assessments, we calculated an index that characterizes the difficulty and effort involved in modifying landscape characteristics in a way that could reduce wildfire hazard. To create the components necessary to map mitigation difficulty, we developed three 30-m resolution raster datasets, as follows:

- Vegetation Life form—We classified the Existing Vegetation Type (LANDFIRE 2014) data set into four life form classes: 1. Barren/Developed/Sparsely Vegetated/Irrigated Agriculture, 2. Grass, 3. Shrub, 4. Tree.
- Slope—We classified the same slope dataset that we used in our fire behavior modeling landscape (LANDFIRE 2014) into three classes: 1. Steep (≥ 30%), 2. Moderate (15-30%), and 3. Shallow (≤ 15%).
- Crown Fire Activity—We used the Crown Fire Activity (CFA) raster output layer from our Basic FlamMap modeling to represent the potential for crown fire. CFA characterizes the potential for fires burning in surface fuels to transition into tree crowns, based on mapped fuel characteristics and modeled wind speeds and indicates if a pixel could experience passive or active crown fire. For the mitigation difficulty index, we collapsed CFA values into two categories: 1. No crown fire potential, and 2. Potential for either active or passive crown fire.

We integrated the spatial layers described above to create map categories representing the difficulty of mitigating wildfire hazard, with difficulty increasing from 1 to 9 (fig. 1D):

1—Non-vegetated, with potential for ember impact

2—Herbaceous on shallow slope

3—Herbaceous on moderate slope

4—Herbaceous on steep slope OR shrub on shallow slope

5—Shrub on moderate slope

6—Shrub on steep slope OR tree on shallow slope

7—Tree on moderate slope OR tree on shallow slope with potential for crown fire

8—Tree on moderate slope with potential for crown fire OR tree on steep slope

9—Tree on steep slope with potential for crown fire.

IMPACT OF THE MAPPING PROCESS

During the CPAW process in Chelan County, team members met with community stakeholders, evaluated community conditions and existing planning documents, and ultimately provided the community with a set of voluntary recommendations to more effectively address the WUI through appropriate land use planning strategies. The hazard, WUI and mitigation difficulty maps aid planners in assessing an existing or future development area for wildfire exposure and also guide implementation of a wildland urban interface code, which delineates standards that might apply depending on levels of exposure and mitigation difficulty. As part of the final CPAW package of products, we delivered a geodatabase containing the final map products, and we provided demonstrations and explanations of data limitations and "best practices" to empower users to take ownership of the data.

Not only do the maps provide spatial context for planning recommendations, but during site visits with stakeholders and SMEs, we found that the discussions that we had about the mapping process were also critically important. Community members affirmed the value of convening multidisciplinary professionals from various agencies to work together on the development of community wildfire hazard maps, ultimately fostering collaborative wildfire risk reduction in Chelan County.

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