10.1071/WF17135_AC

Supplementary Material: *International Journal of Wildland Fire*, 27(5), 329–341.

Supplementary Material

Where wildfires destroy buildings in the US relative to the wildland-urban interface and national fire outreach programs

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Fire outreach and historic fires

To check whether older fires influenced the establishment of some of the outreach communities, we investigated their proximity to a wider time range of fires. Using MTBS fire perimeters from 1990 to 2013 and point locations of national fire outreach programs, we calculated the distance from each national fire outreach location to the nearest fire perimeter, similar to the analysis of the fire perimeters from 2000 to 2013 that is presented in the main part of the paper.

We found that 91% of outreach communities were within 50 km of one of these fires (compared to 89% when using only fires between 2000 and 2013), supporting our finding in the main body of the paper that these communities were established in areas near prior wildfire activity.

Building digitization accuracy assessment

Methods

To assess the accuracy of our building digitization, we compared our counts of destroyed and rebuilt buildings in fires between 2000 and 2013 (henceforth referred to as "digitized") to a number of other data sources. These (henceforth referred to as "reported") included official Incident Command Status (ICS-209) reports, which compile daily records of building damage for fires where these reports are generated (National Wildfire Coordinating Group 2016), and census reports. We also compared digitized counts to visual counts in Google Earth (i.e., double checking our digitized data) for a subsample of fires. Because ICS-209 reports are generated throughout the course of the fire, and counts of destroyed building are not always recorded, many different reported records of building destruction are available. For each reported count of primary buildings and outbuildings destroyed, we utilized the figure from the final record in which a non-zero number was given.

Comparing digitized to reported buildings destroyed first required linking MTBS and ICS-209 fire IDs. We obtained these links from a table providing both for each fire (Short 2014). Because reported buildings destroyed were classified as either primary or outbuilding (indistinguishable in the aerial imagery that we used for digitizing), we established a bounding box where the reported primary buildings destroyed was the minimum and the sum of the reported primary and outbuildings destroyed was the maximum. We expected that the total number of digitized buildings would be within this range. For all fires where digitized destroyed building counts were outside of this bounding box by at least 100 buildings, we visually inspected aerial imagery (via Google Earth) within a few years before and after the fire to identify why the discrepancy occurred.

We also compared total digitized buildings (destroyed plus surviving) against census-based estimates, using census data for the number of housing units per census block from within 5 years of the fire burning (for 2000-2005 fires, the 2000 census was used, and for 2006-2013 fires, the 2010 census was used). Note that this can only be an approximation due to the difference between buildings we digitized (all potential buildings) and housing units as enumerated by the census (only primary buildings included, and each housing unit in a multi-unit building counted separately). Furthermore, the spatial boundaries of fires and census blocks often do not align, which means that it is unknown whether the houses reported for a block were within the portion of the block that burned, or the portion that did not. We thus estimated an area-weighted average by calculating the proportion of each census block (with public areas removed) within a given fire perimeter, and multiplying that proportion by the total number of housing units within that census block. We plotted the census-based, area-weighted average against the number of digitized buildings in each fire, and fit a linear model to the data to determine its correlation and slope.

We also calculated a census-based minimum (summing only housing units in census blocks that were completely contained by a fire) and maximum (summing all housing units in census blocks intersecting a fire). We used the census minimum, maximum, and area-weighted average to create an envelope, which ranged from a minimum value of five buildings less than halfway between the census-based minimum and the area-weighted average to a maximum of five buildings more than halfway between the census-based maximum and the area-weighted average (Fig. S1). The envelope included a buffer of five buildings to avoid situations where the census minimum and area-weighted average were both very low, but would have resulted in an envelope minimum above 0 (despite 0 being a reasonable value; Fig. S1). Because not all fires were digitized, we made an additional visual assessment to confirm that the distribution of 1) digitized fires and 2) over- and under-estimates in comparison to the census-based envelope were not spatially biased.

Results

Digitized fires accounted for 3,087 out of 11,244 MTBS-reported fires between 2000 and 2013, with 3,494 fires during that period having an ICS-209 report. Not all of these ICS-209 reported fires had an ID link to the MTBS database, and not all overlapped with digitized fires, leaving 1,441 fires that 1) were digitized, 2) had an ICS-209 report, and 3) had a link between the MTBS fire ID and the ICS-209 fire ID. As expected, ICS-209-reported numbers of destroyed outbuildings plus primary building counts were generally greater than digitized destroyed buildings, but ICS-209-reported destroyed primary building counts were about the same as digitized destroyed buildings (Fig. S2).

There were six fires where ICS-209-reported primary and outbuildings destroyed (expected to be high compared to digitized counts) were lower than counts of digitized destroyed buildings by at least 100 (Fig. S2). Revisiting Google Earth imagery from immediately before and after each fire, we found that the digitized counts for all six cases were more reasonable than those reported by the ICS-209. There were seven fires where ICS-209-reported primary buildings destroyed were much higher than counts of digitized destroyed buildings (> 100, Fig. S2). In these cases, factors such as buildings obscured by vegetation, temporal gaps between the fire and the image, and irregular housing patterns on the landscape made accurate digitizing a challenge. However, two of the seven fires were found to have been poorly digitized, demonstrating the error inherent in the digitizing product we created.

Comparing digitized buildings to the census-based area-weighted average revealed a strong, significant linear relationship with a slope and intercept very close to the one-to-one line ($p < 0.001$; $R^2 = 0.945$; slope = 0.97), and the census-based envelope contained the digitized number of buildings for 86% of fires (Fig. S3). The spatial examination of over- and under-estimates of digitized buildings in comparison to the census-based envelope revealed no strong biases, but did show a concentration of fires in AK, OK, and TX where digitized building counts were greater than the census-based envelope (Fig. S3). A number of factors make this unsurprising, including a) a house is only one type of building, and there are likely more non-residential buildings (e.g. barns or toolsheds) in those parts of the US, and b) there were generally fewer trees and forests obscuring buildings in the satellite images in these areas. Therefore, this was not an unexpected finding and does not indicate some spatial bias in the digitized building dataset. Overall, our results indicate a robust digitized estimate of buildings destroyed by fire (based on the comparison with the ICS-209 reports), as well as all buildings threatened by fire (based on estimates derived from the 2000 and 2010 US census reports).

References

National Wildfire Coordinating Group (2016) SIT-209. Available at https://fam.nwcg.gov/fam-web/hist_209/report_list_209 [Verified 15 December 2016]

Short K (2014) A spatial database of wildfires in the United States, 1992–2011. Earth System Science Data 6, 1–27. doi:10.5194/essd-6-1-2014

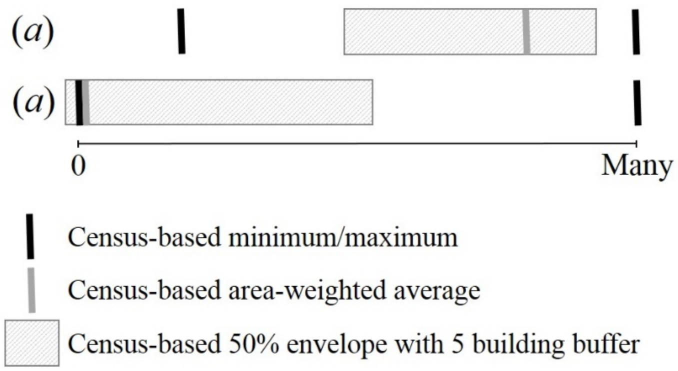

Fig. S1. The envelope used to compare digitized building counts to census-based housing unit estimates for (*a*) a fire with reasonable minimum, maximum, and area-weighted census-based estimates, and (*b*) a fire where the area-weighted average is very close to 0, so the 50% buffered envelope (with 5 building buffer) includes 0, which would be a reasonable value.

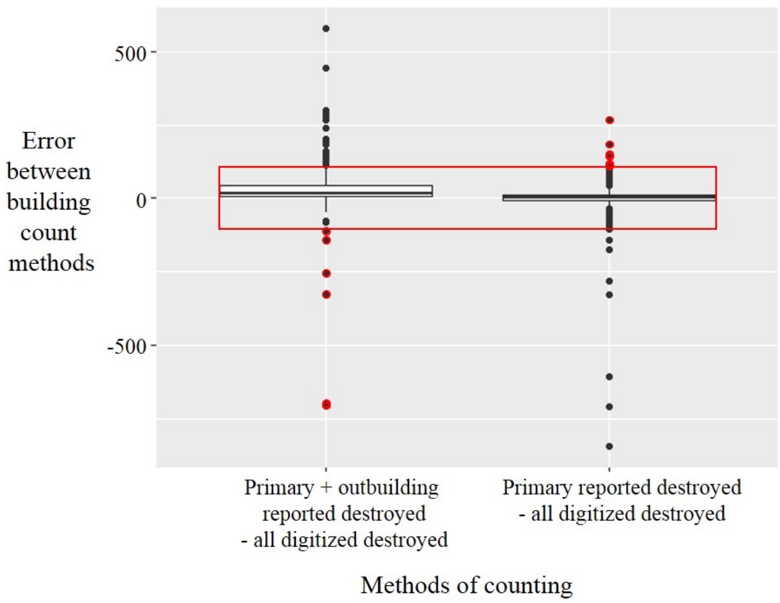

Fig. S2. The residuals for different methods of comparison between digitized counts of destroyed buildings and ICS-209 reported buildings destroyed in each fire. The red bounding box delimits residuals < 100 and > -100. We investigated all fires (shown in red) where (*left boxplot*) reported destroyed primary + outbuildings (expected to be greater) were > 100 buildings fewer than what we had digitized, and where (*right boxplot*) reported destroyed primary buildings (expected to be less) were > 100 buildings above destroyed buildings we had digitized.

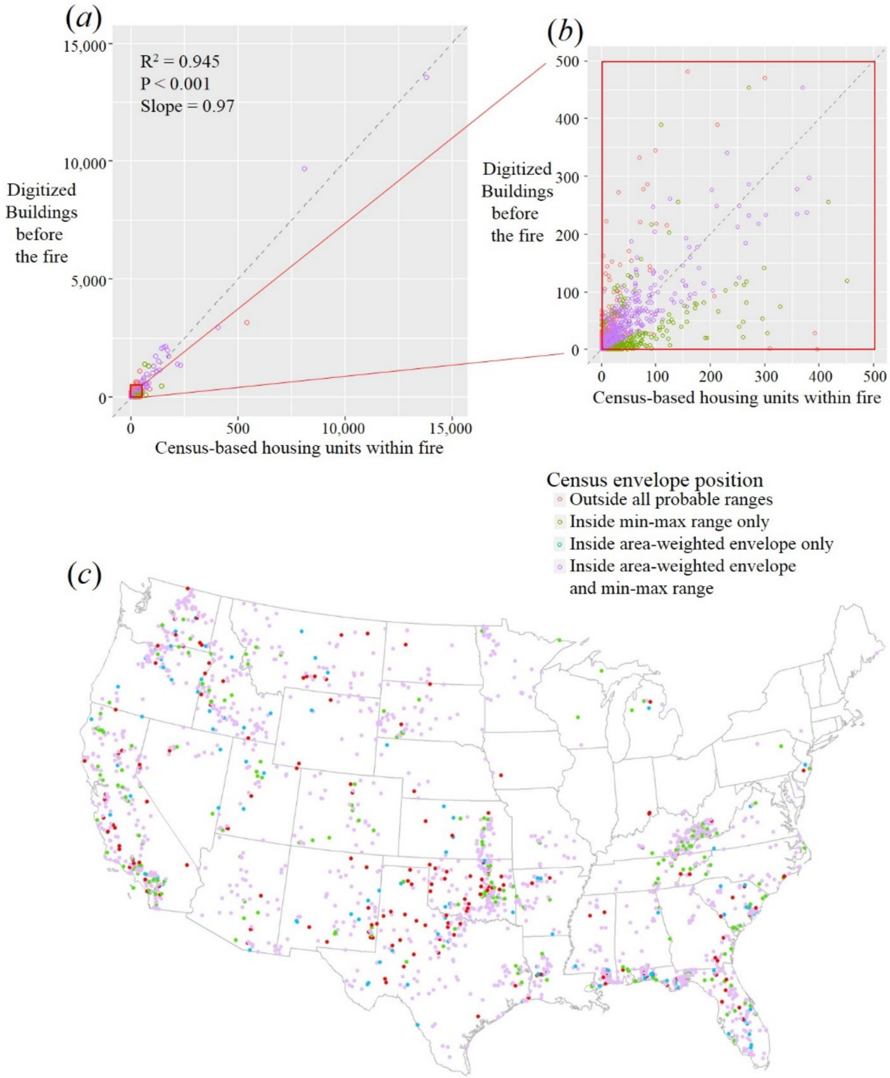

Fig. S3. The number of digitized buildings before the fire compared to an area-weighted estimate of housing units within the fire perimeter based on the US census (points are colored according to the census-based envelope they fall into) and scatterplots (with a 1 to 1 dotted grey line) for (*a*) the full extent and (*b*) zoomed in (outlined in red in *a*). (*c*) Points are also shown spatially across the US, using the same color symbology.