Spatial Patterns of Post-Wildfire Neighborhood Recovery: A Case Study from the Waldo Canyon Fire (Colorado Spring, Colorado, 2012)

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ABSTRACT

Until recently, the recovery phase of the emergency management cycle has received relatively little attention from the natural hazards research community in comparison to the other phases of planning, mitigation, and response. However, in the prolonged aftermath of Hurricane Katrina, studies on recovery have become more common as evidence from this disaster suggests that the process is spatially uneven and temporally dynamic, and operates at finer scales than previously assumed. The heterogeneous patterns of recovery and its implications for the well-being of people and places are especially visible at the neighborhood scale. With growing empirical evidence from post-disaster environments such as New Orleans and Joplin, Missouri, studies on neighborhood recovery are becoming a useful endeavor through which to inform emergency management and city planning policies related to what happens after a disaster, why these outcomes matter, and how to systematically plan for post-disaster recovery. Despite progress made on understanding neighborhood recovery, these studies have focused primarily on post-hurricane and post-tornado environments. In order to achieve a comprehensive understanding of neighborhood post-disaster recovery, other events (e.g. wildfires) must be included. However, wildfires are also notably underrepresented in natural hazards research. This Quick Response project aims to begin to address both the understudied process (neighborhood recovery) and the understudied event (wildfire). It draws attention to the need for post-wildfire neighborhood recovery studies, particularly in order to understand the implications for health outcomes of impacted residents.

BACKGROUND

One of the least analyzed aspects of a disaster is recovery (FEMA and APA 1998; Mileti 1999), and specifically long-term recovery and the health burdens that develop in this process (Curtis, Mills, and Leitner 2007). In particular, the spatial aspects of recovery are dynamic and poorly understood (Mills 2008). Though a number of quantitative variables have been used as proxies for recovery, such as the opening of services, (e.g. childcare centers, hospitals, grocery stores), such metrics only capture city-wide recovery of services and infrastructure. The scale is too coarse to characterize comprehensive recovery at the neighborhood level, which is believed to be a building block of city and regional recovery (Campanella 2006). For this reason, post-disaster neighborhood recovery research is needed to create an evidence base with empirical data upon which recovery planning may proceed.

Collecting empirical data on damage and then the subsequent status of recovery at a fine spatial resolution is especially important in the case of wildfires. The damage pattern of these events in the wildland-urban interface (WUI) varies from contiguous areas that burn, to a seemingly random pattern where one house is destroyed amid others that appear untouched. The fine spatial scale of this damage pattern argues for an equally fine spatial scale of data collection and analysis of damage assessment and recovery. However, wildfires have received relatively little attention from natural hazards researchers. McCaffrey (2004) suggests that this oversight may be due to the timing of natural hazards research that focused on human-environment interaction occurring when wildfire suppression was the dominant management strategy; it was effective enough to render wildfires not considered as a threat to humans (509). However, as residential development has encroached on environments prone to fire (Hammer, Stewart, and Radeloff 2009), and as complete wildfire suppression is not possible in every case, all aspects of wildfires should receive greater attention. This Quick Response project proposes a new framework for studying exposure to wildfires, and in particular to the post-disaster environment which they create, as well as new methods for collecting and analyzing empirical data on damage and recovery at fine spatial and temporal scales.

Theoretical and Methodological Framework. Studies on the health impacts of exposure to wildfires have primarily focused on outcomes linked to particulate matter (PM) produced by these events (Emmanuel 2000; Mott et al. 2002; Künzli et al. 2006; Vedal and Dutton 2006; Naeher et al. 2007; Delfino et al. 2009; Hänninen et al. 2009; Sastry 2009; Wegesser, Pinkerton, and Last 2009; Morgan et al. 2010; Henderson et al. 2011). To a lesser degree, the psychological effects of exposure to wildfire have also been investigated, but with a focus on exposure to the fire event, not its aftermath (McDermott et al. 2005; Jones, Ribbe, and Cunningham 2006). However, drawing on research in environmental justice and environmental health, it may be appropriate to conceptualize the term “exposure” in a broader context. For example, exposure can mean more than a physical encounter with an agent (e.g., smoke inhalation) or with an event (e.g., seeing flames). The exposure-disease framework proposes that exposure to certain toxic agents manifest physiologically in negative health outcomes. Gee and Payne-Sturges (2004) extend this framework to include issues of stress and race. They propose that the relationship between exposure and disease can also be modified by stress whereby stressors act to reduce the body’s capacity to maintain itself thereby placing it at risk for negative health outcomes related to exposure. Typically, this work is focused on health in derelict urban environments and the agents are psychosocial stressors (e.g., signs of physical and social disorder in one’s neighborhood). Observations and anecdotal information from conversations with residents undergoing recovery from natural disasters suggest that it is appropriate to extend this framework beyond urban dereliction in general to the specific case of post-disaster recovery (Curtis, Mills, and Leitner 2007).

However, in order to test the applicability of this theoretical framework, new datasets are needed to capture the a) psychosocial stressors and b) exposure to the psychosocial stressors in a post-disaster environment. This Quick Response project employs an emerging geospatial technology, spatial video, to capture neighborhood recovery from the Waldo Canyon Fire in Colorado Springs, Colorado. With this technology, neighborhood characteristics can be captured and digitized in their real-world location in a map. Then, at different time intervals, the neighborhood survey can be repeated and the neighborhood characteristics mapped again. The result is the ability to analyze the spatio-temporal patterns of variables hypothesized to be psychosocial stressors. Specifically, in the case of this post-wildfire environment, three variables are believed to be potential psychosocial stressors to residents who return to the damaged neighborhood: 1) severely damaged parcels, 2) parcels that demonstrate stagnation in recovery (e.g., persistent vacancy, persistent blighted (damaged) lots), and 3) burned land (not residential). All of the variables are visible to returning residents and all are reminders of the wildfire.

In order to calculate residents' exposure to these characteristics, a novel application of viewshed analysis is applied. A viewshed is a geographic scale that captures the entire visible area from an observation point at a specific location; this is a common approach used in studies of visual impact. Despite their potential for meaningfully capturing visual exposure to environmental characteristics, they have not been employed in studies examining neighborhood recovery and its health implications. Therefore, this project is a first step to employing a new theoretical frame, as well as novel data collection and analysis approaches to understanding how post-disaster environments impact health outcomes.

Research Questions. The specific objectives of this Quick Response project are twofold. First, the spatial video approach will be used to collect neighborhood recovery data in the study area at two intervals (6 months and 1 year post-event). Second, these data will be used to map the spatial pattern of recovery using the Recovery Score (RS) method developed and tested in other post-disaster environments including New Orleans, San Diego, Joplin, and Tuscaloosa (Curtis et al. 2010). Addressing these objectives is central to establishing the neighborhood environmental conditions, and the characteristics which can be identified as psychosocial stressors. With these data, the RS and other visible environmental variables can eventually be integrated with health self-reports to measure health outcomes.

As recovery is a spatially and temporally dynamic process, fieldwork on this project is occurring at two time intervals: six months post-event and one year post-event. Consequently, two Quick response Reports will result from this work. This report, Report #1, will detail the methods used for data collection using spatial video and the Recovery Score (RS) in a Geographic Information System (GIS). Substantively, it will focus on mapping the spatial patterns of neighborhood recovery from 6 months post-wildfire by using the RS for all damaged parcels in the study and then creating viewsheds of all neighborhood parcels for calculating exposure of each parcel to severely damaged parcels and burned land. These results will be used to identify areas where residents are theoretically at risk for negative health outcomes due to exposure to the aftermath of the wildfire. Furthermore, the investigators will compare RS patterns at the 6 month post-event mark between the area impacted by the Waldo Canyon Fire (Colorado Spring, CO - 2012) with patterns at the same time interval in the study areas impacted by the Witch Fire (San Diego County, CA - 2007).

Report #2 will serve as the comprehensive documentation of both data collection trips, the comparison of neighborhood recovery patterns at both time intervals between the San Diego study area and the Colorado Springs study area, and will build on the substantive and methodological issues presented in Report #1. Specifically, it will focus on a) comparing the spatial patterns of neighborhood recovery from 6 months post-wildfire and then from 1 year post-wildfire using the RS approach to spatial video coding in GIS, b) identifying parcels that demonstrate persistent signs of severe damage, or of stagnation, c) creating viewsheds of all neighborhood parcels for calculating exposure of each parcel to damage, stagnation ,and burned land, and d) using the results from viewshed analysis within the exposure-disease framework to hypothesize about health outcomes. A follow-up study will then collect self-reported health data from participants in order to look understand how the post-disaster neighborhood environment impacts health. By using Report #1 to establish a baseline, Report #2 will show the dynamic spatiotemporal characteristics of post-wildfire recovery, even in micro-environments (e.g., the changes that occur within a neighborhood). Based on the similar levels of damage and socio-demographic variables, the investigators expect that patterns of recovery from this study will be similar to patterns of recovery from the Witch Fire at both time intervals. However, due to the compounding factor of initial stages of the national economic crisis occurring during recovery from the Witch Fire, less stagnation and decline may be evident after the Waldo Canyon Fire.

Overall, the empirical documentation provided in Reports #1 and #2 will argue for further study of post-wildfire neighborhood recovery at final spatial scales, extended temporal scales, and with a justification of why health implications of wildfires cannot be theorized as being linked only to exposure to the immediate event. In addition to the intellectual contribution of this project, Report #2 will serve as an applied outline for policy-makers, planners, and emergency management professionals of how such an approach can be implemented.

METHODS

Study Area. The Waldo Canyon Fire began on June 23, 2012. Before it was contained on July 10, the fire burned 18,247 acres, destroyed 350 homes, and caused two deaths. It has been described as the most destructive fire in Colorado history. Much of the damage to homes occurred in the Mountain Shadows neighborhood of Colorado Springs. The study area encompasses the areas west of Centennial Boulevard, south of the intersection of Flying W Ranch Road and Centennial Boulevard, north of the intersection of Flying W Ranch Road and N 30th and east of Pikes Peak National Forest (Figure 1). This residential area is similar to the Rancho Bernardo and Bernardo Trails areas of San Diego County where our previous wildfire study was conducted based on race, socioeconomic status, and location in the WUI (Figure 2)[1]. Therefore, this neighborhood will provide an appropriate comparison to results from the 2007 Witch Fire in California.

Data Collection. One of the biggest impediments to extreme event recovery analyses is the challenge of data collection. Until recently, no data collection strategy that is systematic, dynamic, cost-effective, and transferable among disasters has been available. In order to address this concern, the investigators employed a geospatial approach, spatial video, which links video with coordinates acquired by a Global Positioning System (GPS) receiver, developed and perfected in the post-Katrina neighborhoods of Orleans and St. Bernard Parishes in Louisiana; San Diego County, California; Tuscaloosa, Alabama; Joplin, Missouri, and Madison and Shelby

[1] According to American Community Survey (ACS) 5-year estimates for 2011: Median Household Income for the San Diego County Study Area = $83,929; for the Colorado Springs Study Area = $75,171.50

Counties, Tennessee (Curtis, Mills et al. 2007; Mills, Curtis, et al. 2008; Mills et al. 2008; Curtis, Mills et al. 2010; Mills et al. 2010; Burkett and Curtis 2011; Curtis and Mills 2011). This approach enables increased efficiency in field data collection, as well as the ability to survey locations over multiple time periods in order to analyze spatio-temporal phenomena. In addition, unlike existing survey methods, this approach generates archival data so that places can be revisited through the video. This archival aspect allows data to be used for subsequent investigations, even for studies not related to the initial research question. A benefit of this system is that it enables analysis of both spatial and temporal elements (Curtis, Mills, McCarthy, et al., 2010). For example, if a neighborhood is driven at different times over the course of a year, then the houses in the neighborhood can be coded based on their recovery status at each time. Empirical work in New Orleans indicates four stages of residential recovery: damaged structure/remains, cleared lot, emerging structure, and complete structure. These phases are then coded as a Recovery Score (RS) of one through four (Curtis, Mills, McCarthy, et al., 2010). Using the RS, improvement, stagnation, and decline can be captured for disaster-impacted neighborhoods. The technology and methodological approach used in this research forms the basis of a standardized recovery analysis suitable for any post-disaster investigation.

Fieldwork for this project was performed from November 29th, 2012 through December 1st, 2012. This time frame is significant in that it represents the six month mark since containing the wildfire in June 2012. The neighborhood surveying process was completed by driving through the areas impacted by the wildfire and collecting video data using a total of four high definition spatial video units. Each side of the vehicle was equipped with two spatial video cameras, one facing slightly forward and one facing slightly backward to best capture the full range of sight of each street. The area of interest for this project is centered near the Mountain Shadows neighborhood which is located in the north-western part of the city of Colorado Springs. In addition to the spatial video approach, visual observations also provided valuable insights into the magnitude of the wildfire's impact on the built environment as well as the current status and pace of the post-disaster recovery efforts.

The research team, consisting of two graduate students who are part of Kent State University's GIS | Health and Hazards Laboratory, initiated the neighborhood surveying in the southern part of the study area and gradually made their way to the northern part of the area by driving the entire street network. Spatial video data were collected for all of the areas impacted by the Waldo Canyon Fire with the exception of the Flying W Ranch, those areas along Chuckwagon Road located east of the intersection of Chuckwagon and Rossmere Streets.

Following the field data collection process, data preparation and visualization were accomplished by employing a mixed approach of playing the videos through a spatial video data visualization software (Contour Storyteller) and coding recovery scores in ESRI's ArcGIS mapping software. Parcel level data were used to assess neighborhood recovery by assigning a recovery score between one and four to each property parcel located in the disaster affected neighborhood. Recovery scores reflect the characteristics of a damaged structure (RS=1), a cleared lot (RS=2), an emerging structure (RS=3) or a completed structure (RS=4). The data layer obtained from the recovery coding process will be used to visualize spatial patterns of the post-disaster neighborhood recovery efforts and assess the visual impacts of the wildfire affected areas, more specifically their influence on health-related outcomes of returning residents.

Analysis. For this study, spatial video was used to collect the current status of the neighborhood approximately six months after it sustained damage from the Waldo Canyon Fire. Using this video survey, each parcel was coded using the Recovery Score (RS). The result is that, for each time period, a spatial pattern of recovery is visualized. These data can then be used in a study of exposure to wildfire damage where exposure is defined in the longer-term sense of returning residents continuing to look out on fire damage. This psychosocial exposure will be calculated by the viewshed for each house, which is possible to achieve in three-dimensions using data from the spatial video rendered in ArcScene software. In order to calculate these exposures a viewshed was calculated around the centroid of each parcel, and with the number of houses that burned and the amount of burned land calculated for each viewshed. From these calculations, each parcel was classified by the percentage of damaged properties and burned land in visible area. These data on exposure to theorized psychosocial stressors are central to a subsequent study investigating the relationship between the neighborhoods in recovery and health outcomes of residents.

RESULTS

Wildfires are known for creating heterogeneous patterns of residential damage. Therefore, using the RS, it is not surprising that most of the properties in the study area (80.91%) show no sign of damage. Some of these houses have been rebuilt, but also many were not impacted by the fire at all. Table One provides an overview of the status of parcels in the study area based on RS and the spatial pattern of the RS is presented in Figure Three. These data present the baseline of damage and recovery in the study area at six months post-event. As a point of comparison, Figure Four shows the approximate 6-month status of the neighborhood in the Waldo Canyon Fire study area in Colorado Springs with a neighborhood in the Witch Fire study area in San Diego. Note the numerous parcels colored in red on the Witch Fire example. This indicates parcels where damaged structures are still visible. The comparison demonstrates that recovery may be occurring faster in the Waldo Canyon case. However, this statement cannot be made with any confidence until subsequent neighborhood surveys are conducted to provide confirmation that recovery has indeed occurred, rather than stagnation (e.g. cleared lots remaining as cleared lots over an extended time period).

With the baseline data established using the RS, viewshed analysis can be performed to calculate each parcel’s exposure to each environmental characteristic. In this case, the analysis is used to assess exposure to damaged properties and burned land. Stagnation cannot yet be coded as multiple neighborhood surveys are needed to make this determination. Figure Five shows examples of the viewshed for a parcel in the a) Waldo Canyon Fire study area and b) the Witch Fire study area. Using this geography and the data collected from the spatial video neighborhood survey in concert with aerial imagery, exposure to burned properties and exposure to burned land can be calculated for each parcel’s viewshed. Figure Six displays the patterns of exposure to these two potential psychosocial stressors for each parcel. It is evident that different patterns of exposure emerge based on the variable (burned property or burned land), but that even within this neighborhood, two smaller areas of exposure exist in the northeast and in the central parts of the study area. Again, as a point of comparison to proposed psychosocial stressors in post-disaster environments, Figure Seven shows each parcel’s exposure to burned land area in the a) Waldo Canyon Fire study area and the b) Witch Fire study area. Due in part to differences in elevation and surrounding topography, the neighborhood in the Witch Fire study area experienced greater exposure to visible burned land. However, referring back to Figure Four, this same area had problems with persistent signs of damage and stagnation in recovery. Though it is too early to draw any conclusions about neighborhood recovery from the Waldo Canyon Fire, to date it appears that it is progressing more quickly and more comprehensively than the comparison neighborhood impacted by the Witch Fire. Further data collection and analysis presented in Report #2 will yield more ability to draw conclusions.

DISCUSSION

Using the exposure-disease framework to broaden understanding of the health implications of wildfires requires re-thinking what "exposure" to an event actually means, both in terms of space and time. Extending the definition to include the environment to which people return and live in long after the wildfire has been extinguished then means that we need relevant data on this environment and on resident health. This study provides the method for data collection, spatial video, for acquiring appropriate description of the environmental component. It also provides a new scale of understanding exposure to this environment through viewshed analysis. Of course, this is just a first step toward more comprehensive studies that test the relationship of exposure to characteristics of a post-disaster environment with health outcomes. However, given the dearth of research on wildfires in general and on post-disaster recovery in particular, it is an important first step.

Despite intellectual contributions of theoretical framework and methods, ultimately the aim is to produce work that is useful for decision-makers. To this end, while in the field, the data collection team met with local government and non-profit leaders to present this work and to receive their feedback. As a result of these meetings, the following potential collaborations were identified:1) use geospatial technologies to assess the post-disaster recovery of the natural environment, 2) apply geospatial technologies in order to conduct risk assessments of land slide events as a direct result of the vegetation loss from the fire, and 3) assess the long term impact of wildfires on the health outcomes of residents, especially of residents whose properties were not directly impacted by the fire but whose living conditions were altered by the infiltrating smoke, dust, and particulate matter. Furthermore, there is also potential to create collaborations with local students to decrease the time interval between data collection. Finally, with an intention of conducting research with actionable results, the video surveys are made available online through the Outreach role of the GIS Health & Hazards Lab (http://www.kent.edu/ghhlab/outreach.cfm).

CONCLUSION

The benefits of the project address both applied and theoretical interests. First, by leveraging existing work with the new field data collected through Quick Response support, this project will ultimately result in the development of a measure of post-disaster neighborhood recovery that is temporally sensitive and can be universally applied. In this way, after any disaster, data can be collected at the same places over extended time periods to assess the extent and quality of recovery. If recovery for one neighborhood is not progressing either as one would expect based on other disasters, or as compared to other neighborhoods, then more aggressive intervention strategies can be justified and spatially targeted. Second, these data will provide a baseline upon which the exposure-disease framework may be tested, specifically that the degree of damage and stagnation in a neighborhood impact residential recovery and that exposure to the resulting environment has implications for health outcomes of the returning residents. In essence, this research will build theory on spatial patterns of neighborhood recovery and the health implications of these patterns. This research is in its infancy, but is has the potential to bring together existing work in health and hazards to yield understanding of the relationship between environment and health after disasters, and to use this understanding to target interventions and to inform recovery planning policy.

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Table 1. Recovery Score (RS) of Parcels in the Waldo Canyon Fire Study Area

RS	Number of Parcels	Percentage of Parcels	Number of Burned Parcels	Percentage of Burned Parcels
1	0	0%	0	0%
2	298	16.49%	296	79.36%
3	47	2.60%	41	10.99%
4	1462	80.91%	36	9.65%
TOTAL	1807	100%	373	100%

Figure 1. Waldo Canyon Fire Study Area

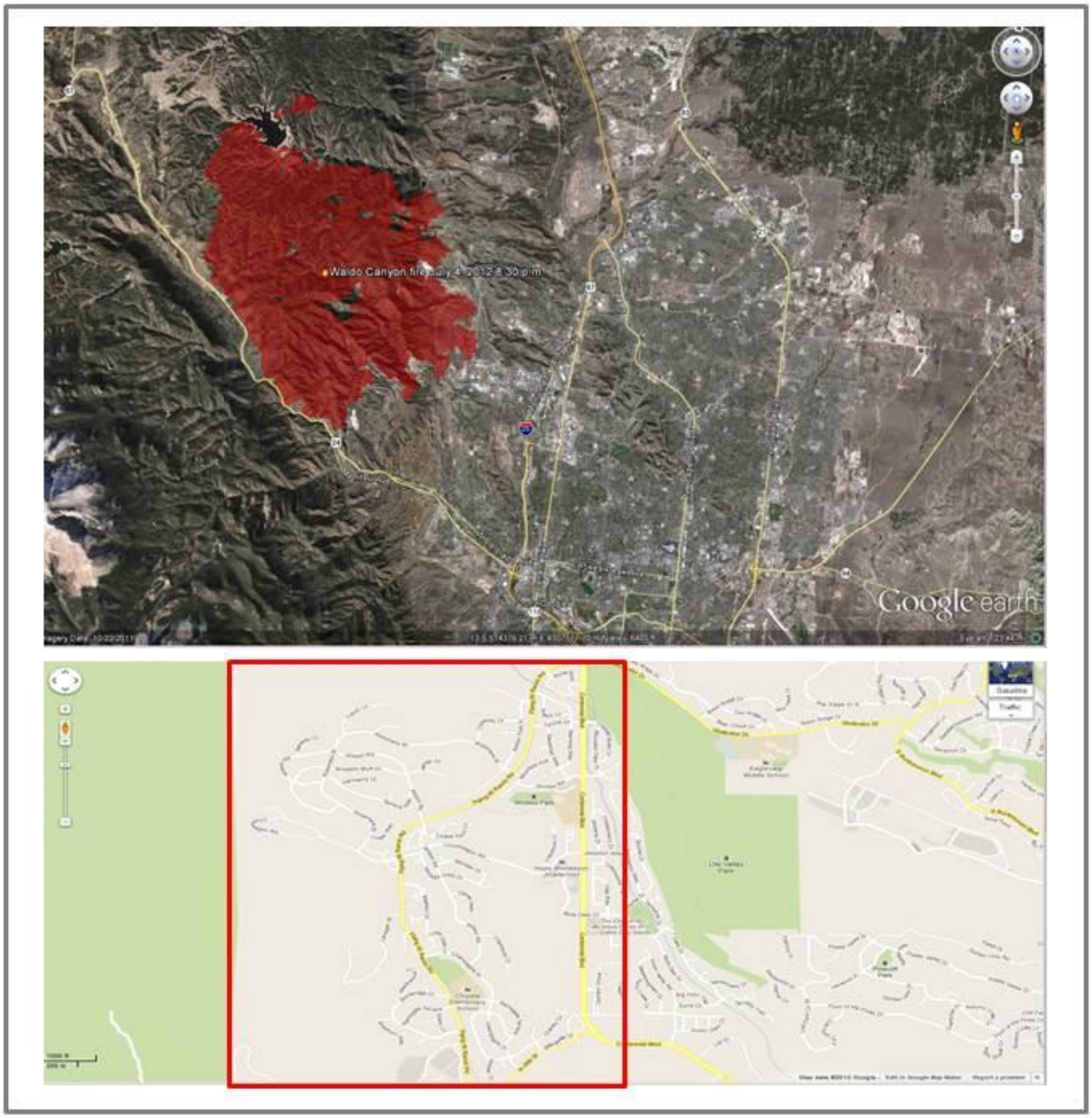

Figure 2. Witch Fire Study Area

Figure 3. a) Map of the Recovery Score (RS) of Parcels in the Waldo Canyon Fire Study Area and b) in Comparison by Burned Areas (outlined in red). Yellow = Cleared Lot, Light green = Evidence of Rebuilding, Dark Green = No Evidence of Damage

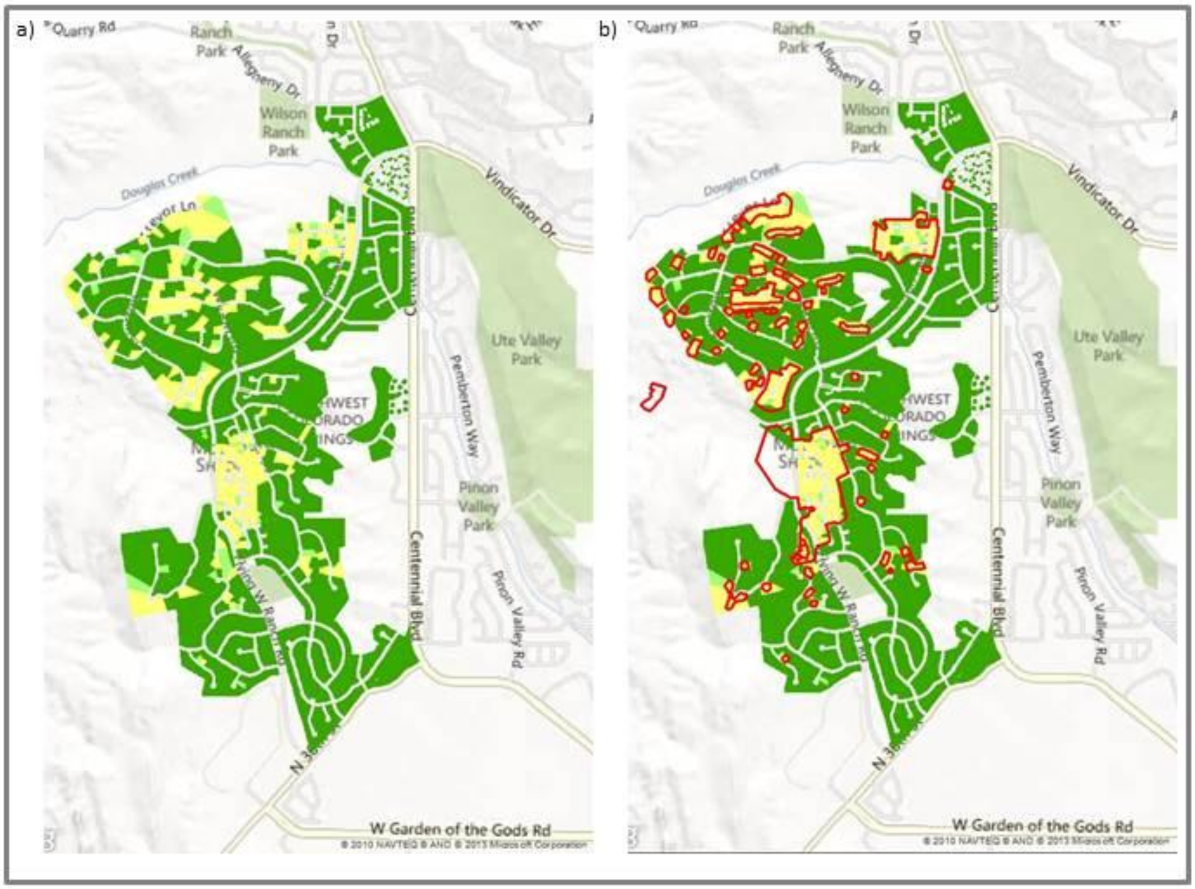

Figure 4. a) Six month post-event map of the Recovery Score (RS) of Parcels in the Waldo Canyon Fire Study Area and b) in the Witch Fire Study Area.

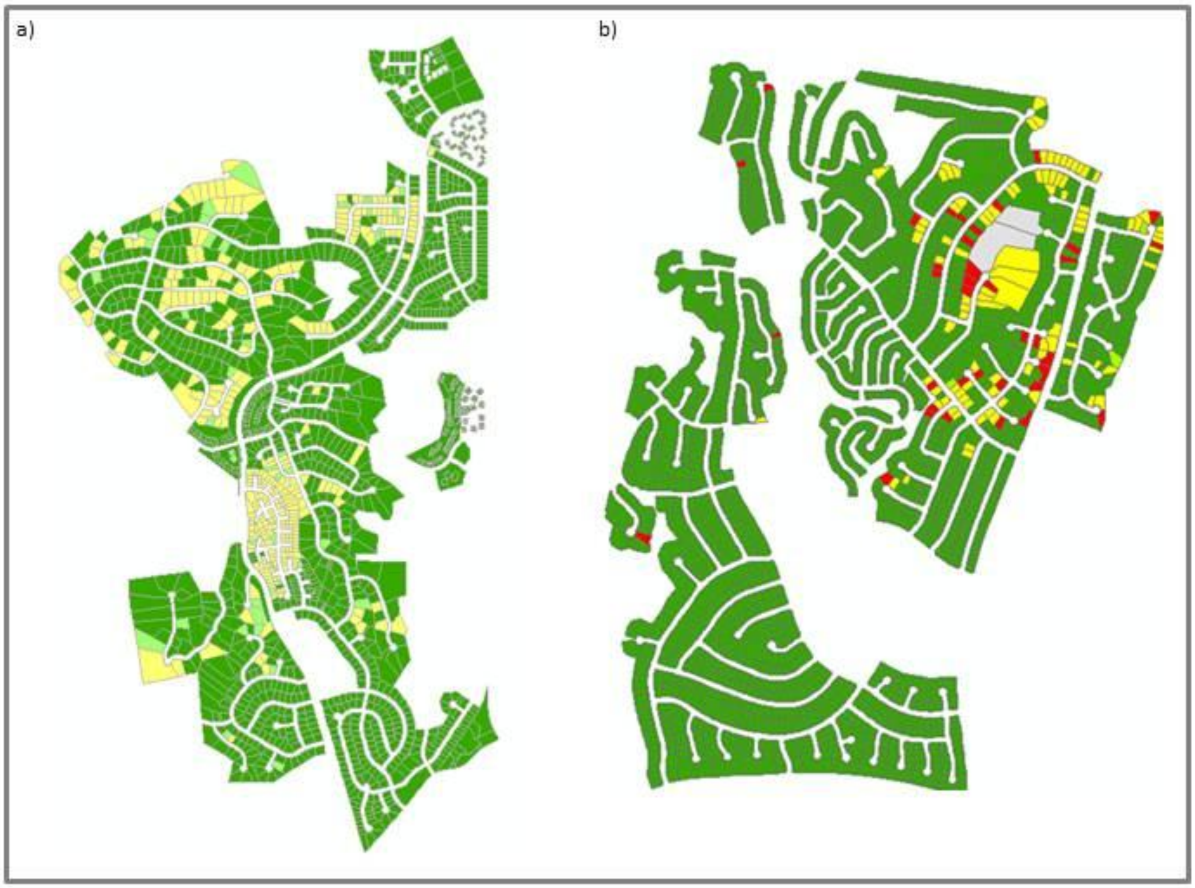

Figure 5. Example of the viewshed for one parcel in the a) Waldo Canyon Fire study area and b) Witch Fire study area. The parcel is identified with a yellow point in each image.

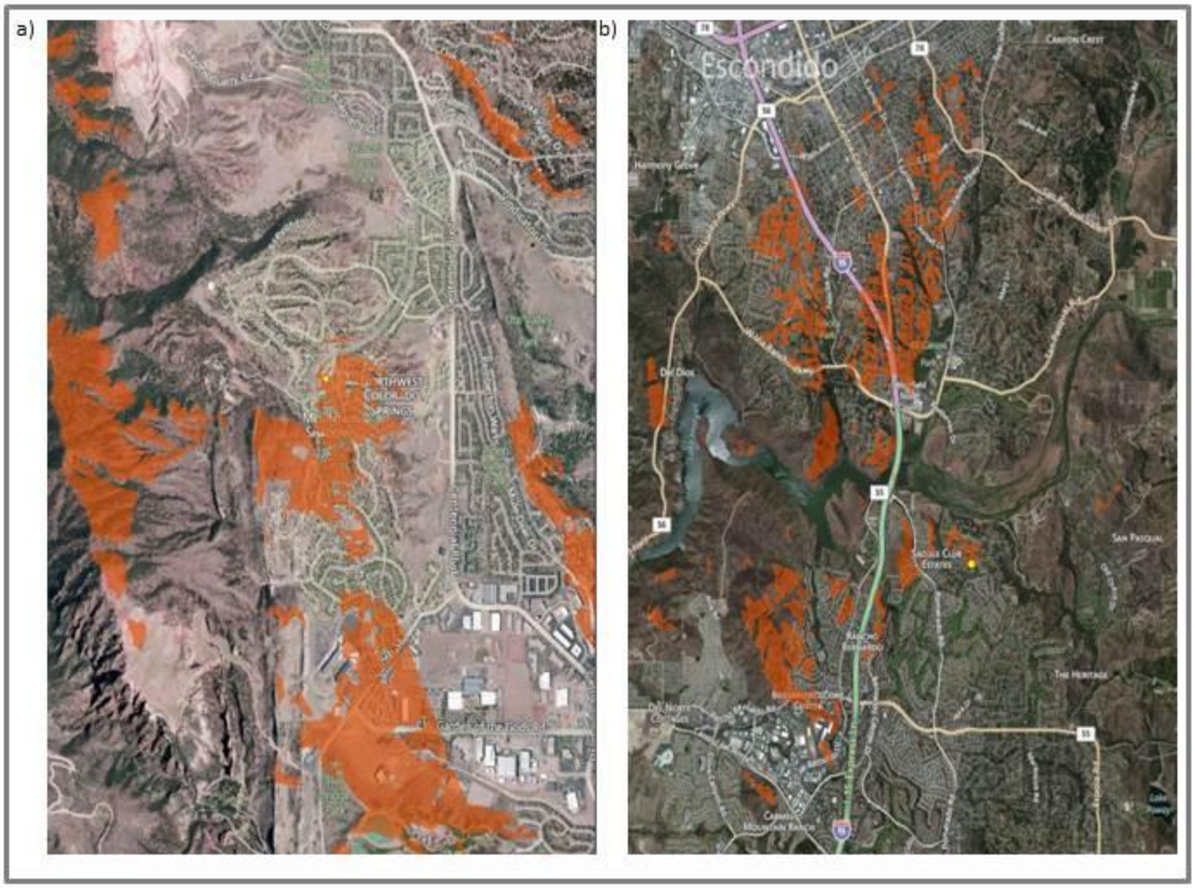

Figure 6 a) Waldo Canyon burned properties in viewsheds b) burned land area in viewsheds. Exposure is derived by calculating the number of a)burned properties and then b) burned land area in the viewshed of each parcel and then assigning these values to the centroid of the parcel. The resulting maps display these exposure patterns: White = No Exposure, Yellow = Low Exposure, Orange = Moderate Exposure, Red = High Exposure.

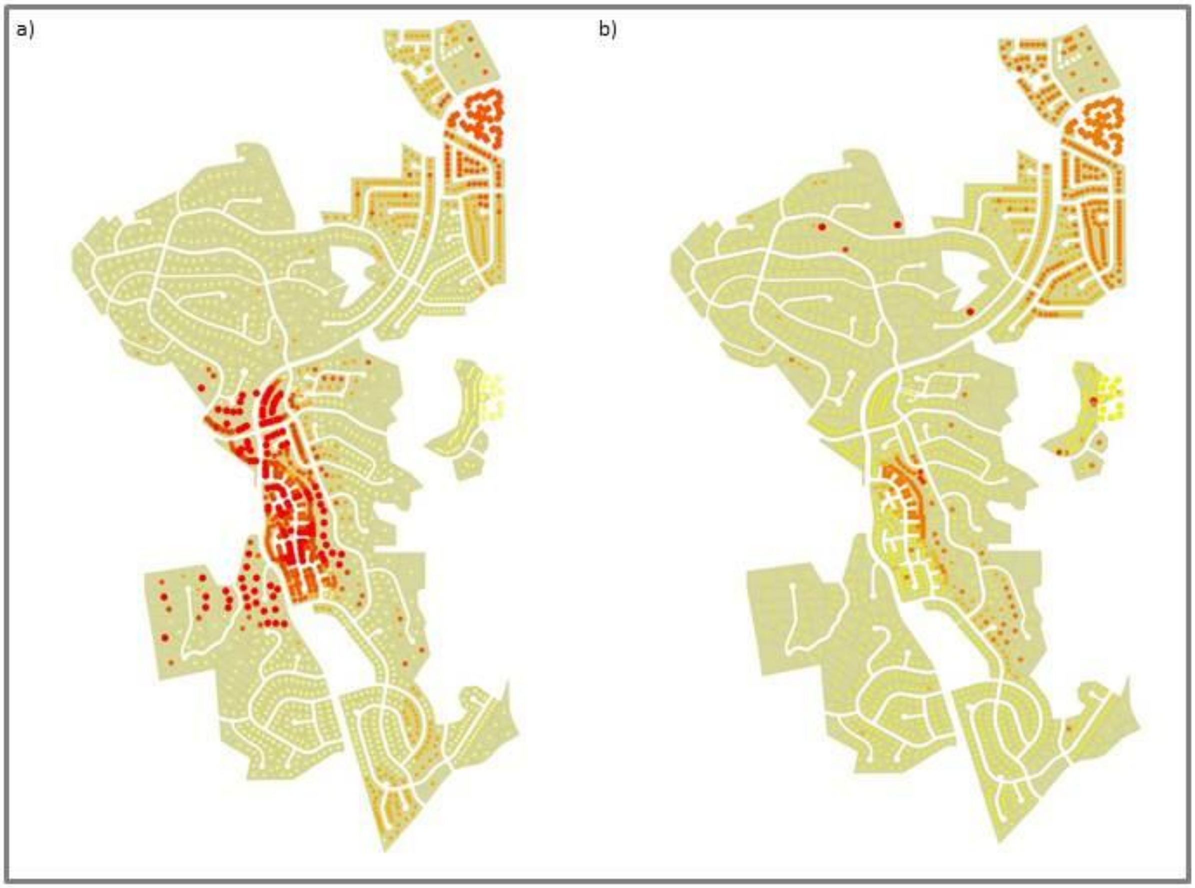

Figure 7 Comparison of burned area in viewshed a) Waldo Canyon, b) Witch Fire. Exposure is calculated using the same method described in Figure 6. The resulting maps display these exposure patterns: White = No Exposure, Yellow = Low Exposure, Orange = Moderate Exposure, Red = High Exposure.