Title:

Is there a link between actual and perceived wildfire danger?

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Abstract:

Over the last 20 years, costs for wildfire initial attack in the U.S. have increased significantly. The increased cost relates to wildfire suppression practices as well as the growing number of wildland urban interface (WUI) homes. Requiring WUI residents to pay an annual tax for their wildfire risk would lower costs to the general taxpayer. Willingness-to-pay (WTP) for wildfire prevention, in relation to both perceived and actual wildfire danger, was the focus of this study. Colorado WUI residents had a high awareness of wildfire risk and were willing to pay over $400 annually to reduce this risk. Respondents beliefs about wildfire frequency were comparable to the original natural wildfire regimes of their areas pre-European settlement.

Keywords:

GIS; wildfire risk; stakeholder; contingent valuation; Colorado.

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1. Introduction

Euro-American land use practices have changed wildfire regimes in the United States. Dry landscapes that once experienced frequent low-intensity wildfires now experience infrequent high intensity wildfires (Allen *et al.*, 1998 and 2002; Covington and Moore, 1994; Swetnam, 1999; Cooper, 1960; Mutch *et al.*, 1993; Arno *et al.*, 1995; Fule *et al.*, 1997; Veblen *et al.*, 2000). Over the last 20 years, the number of wildfires reported by U.S. Wildland Fire Agencies has decreased from 1.872 million (1975-1984) to 884,000 (1995-2004), but the total area burnt has increased by 11 million acres (to 47.750 million acres). As a result, the cost of wildfire suppression and initial attack has increased from $256 million in 1997 to $1.326 billion in 2003 (NIFC, 2004).

The increase in cost is not only a result of wildfire suppression practices, but is also linked to the significant influx of homes into forested areas – termed the wildland urban interface (WUI). Reducing the actual wildfire danger to WUI homes would reduce this cost, and can be accomplished, in part, by creating defensible space (Vicars, 2003; WHIMS, 2002; VCFCA, 2000; Romme, 2003; Larimer County, 2003; Stewart *et al.*, 2003).

Defensible space is a clear area free from flammable objects that surrounds the home (WHIMS, 2002; Larimer County, 2003). For buildings, it is recommended that metal shingles be used instead of wood, spark-arrestor chimney caps be installed, dead leaves and pine needles cleared from roofs, and firewood, gas and propane be stored beyond the 30 meter perimeter. (Vicars, 1999; WHIMS, 2002; Larimer County, 2003). Between 30 and 100 m from the house, any dead or lower tree-limbs should be removed and lawns kept below three inches in height (Vicars, 1999; VCFCA, 2000; WHIMS, 2002; Larimer County, 2003).

Homes with defensible space survived the 2002 Colorado Missionary Ridge Fire and some homes with defensible space even survived the 2002 Hayman Fire, the largest wildfire to hit Colorado in written history (Binkley, 2003; CUSP, 2003). Despite the apparent benefits, creating a defensible space is still not mandatory in most of Colorado. Of the four counties involved in the Hayman Fire, Teller, Park, and Douglas Counties did not have defensible space regulations in place for wildland-urban wildfire risks at the time of the wildfire, and it is believed that regulations have not changed since. Jefferson County requires a defensible space, but only on homes over 122 m^2 that were built after 1996. While most homes did fit the size qualifications, they were built prior to 1996 and therefore few fell into this category (Cohen and Stratton, 2003).

In addition to defensible space, several other variables determine the actual wildfire danger to wildland urban interface (WUI) homes. These include the type of vegetation surrounding the home, slope of the land and the proximity of previous wildfires (Vicars, 2003; WHIMS, 2002; VCFCA, 2000; Romme, 2003; Larimer County, 2003).

Vegetation is one of the most important aspects to consider in wildfire risk because it provides the wildfire fuel. In Colorado, the vegetative landscape includes a variety of classes, each with their own wildfire regimes (Romme *et al.*, 2001; Theobald *et al.*, 2003). Brown *et al.* 1999, studied wildfire events in the Cheeseman Lake forest, a 4000 ha area of montane ponderosa pine and Douglas fir in central Colorado. They recorded 486 wildfire scars from the years 1197 through to 1999. The interval between wildfires varied across this landscape and ranged from 1 to 29 years for most of the area, to 1 to 10 years in areas more prone to wildfire, and over 100 years for a few areas with very long wildfire intervals.

Veblen *et al.* 2000, studied ponderosa pine forests at elevations of 1830 to 2800 meters in the northern Colorado Front Range. Lower elevation ponderosa pine forests were found to experience frequent surface wildfires. By comparison, high elevation ponderosa pine – Douglas fir – lodgepole pine forests had a lower frequency of wildfire, but wildfires were stand-replacing.

After characterization of the vegetation, it is important to consider the slope of the land. The steeper a slope, the faster the rate of wildfire spread, so a building on a steep slope faces a higher wildfire hazard. Wildfires do occur on flat land, but the risk that the wildfire will reach the home is significantly less (Ryan, 1976).

Recent wildfire occurrence is also an important determinant of actual wildfire risk. If a wildfire went through an area in the past few years, the chances of a high intensity wildfire occurring is lower in that area because there will be less fuel available to burn.

For this study, it was hypothesized that both the perceived danger and actual danger of wildfire would affect willingness-to-pay (WTP) for wildfire management by Colorado WUI residents. To test the hypothesis, Colorado residents living at the WUI were interviewed to determine their perceived risk of wildfire and their WTP to reduce this risk. Next, actual risk of wildfire was estimated for each home using spatial analysis of vegetation, slope, and previous wildfire locations.

2. Methods

2.1. The survey

People in the WUI were surveyed to determine perceived risk of wildfire and WTP for wildfire management. A survey booklet was created entitled, "Managing Wildfires on Public Lands: What Do You Think?" The survey was tested with a series of focus groups in California and Colorado to improve wording of the survey and to determine the value range for the WTP question. The updated survey was again tested on a selected group of random Colorado WUI residents and their comments were used to finalize the survey before distribution to recipients. The final version included eight pages of questions, a picture representing a ponderosa pine forest one year after a low intensity prescribed burn, and a picture of similar forest one year after a high intensity wildfire. Pictures were used in conjunction with wildfire questions to help respondents with the conceptualization process. Forests in both pictures were similar in tree size (diameter at breast height) and stand density (trees per hectare) (Kaval, 2004; Kaval *et al.*, 2007; Kaval and Loomis, 2007).

Selected participants lived within ten miles of undeveloped National Forest or National Park land in Colorado. A total of 115 people were contacted randomly by phone during the summer of 2001 and asked to participate in the survey. Participants completed the mail survey and a follow-up phone interview to discuss survey questions further. The response rate was high with 86% of the people contacted agreeing to participate in the survey (103 out of 115) and 96% of participants completing the process (99 out of 103).

Three survey questions were central to the study. The first question asked respondents if they felt their home was in danger of wildfire. To answer this, they could simply respond by ticking a 'yes' or a 'no' box. The second question asked respondents an open ended question regarding how often they felt that high-intensity wildfires occurred in their area. The ponderosa pine photos alongside definitions of high and low intensity wildfires were presented to aid respondents with this question. Responses included answers such as twice a year or once every 30 years.

The third question was the WTP question. The contingent valuation method was used to elicit WTP, as recommended by Pearce and Turner (1990), Freeman (2003) and Carson (2000). Prior to asking the WTP question, wildfire prevention was defined as fuel reduction by thinning. The definition and two photographs enabled respondents to answer the WTP question:

> *Using wildfire prevention techniques, public land management agencies could reduce the frequency of high intensity wildfires in the National Forests and/or National Parks in your area by half. Would you pay an increase of $X a year more in taxes for a program such as this? (Circle One) Yes No*

The dollar value ($X) varied between surveys with a range of $5 to $1500 determined during the focus group sessions.

2.2. **Spatial analysis**

The actual danger of wildfire was assessed for the properties of people responding to the survey. Actual wildfire danger variables included defensible space, vegetation type, slope and previous wildfires. These variables were estimated using spatial analysis of 4 map layers: vegetation, home point locations, slope, and wildfire locations. The analysis was completed using GIS software (ArcView 8.2).

Property specific information was collected during site visits for 73 homes and included: 1. the UTM coordinates obtained with a Garmin Global Positioning System (GPS) unit; 2. the degree to which a 30 meter defensible space was created (WHIMS, 2002; Larimer County, 2003); 3. general vegetation characteristics; and 4. pictures of the home and the surrounding area. The 30 m defensible space zone was assessed as present or absent during the site visit. For the purpose of this survey, a defensible space was scored as present if there was a 30 meter clearing around the perimeter of the home, with no flammable material (e.g. wood piles or propane tanks) and no observed debris on roofs. Houses located in a town area with no danger of wildfire were also scored as having a defensible zone. Out of the 73 properties assessed, 23 had either the proper defensible space and/or were located in a town area where there was no wildfire danger.

The vegetative zone analyzed included the 100 meter perimeter surrounding the home as recommended by Vicars (2003), WHIMS (2002), VCFCA (2000), Romme (2003) and Larimer County (2003). Information on the vegetation for this zone was obtained by spatial analysis of the vegetative map layer. The vegetative map layer is a fine grained (~1 ha) statewide landcover map of Colorado that is based on the National Land Cover dataset (Theobald *et al.*, 2003). Although finer-grained vegetation maps are available for National Forest land, they do not extend onto private land. For each location, the type and amount of vegetation within the 100 m buffer was calculated. For example, the vegetation within the 100 meter buffer of one of the respondents homes consisted of 1.8 hectares of ponderosa pine montane, 0.27 hectares of ponderosa pine/ Douglas fir, 0.63 hectares of lodgepole pine and 0.36 hectares of short grass prairie.

Data presented in Table 1 (from Romme *et al.* 2001) was used to calculate the heat release[1], spread rate[2], and flame length[3] for the vegetation surrounding each property. This analysis was completed using GIS and BEHAVE (a wildfire behavior model).

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1 "Heat release (btu/ft2), an indicator of the total potential damage from a wildfire, varies with fuel model type and fuel moisture, but is independent of slope and wind (Romme *et al.*, 2001)"

2 "Rate of spread (chains/hour where one chain is 66 feet) is affected by fuel model, fuel moisture, slope and wind (Romme *et al.*, 2001)"

Table 1. Wildfire Danger Statistics.

Vegetation type	Average flame length	Average spread rate	Average heat release
Urban, open water, tundra	0.000	0.000	0.000
Dryland crops, irrigated crops, riparian vegetation, subalpine meadow	2.567	23.000	116.000
Foothills/ mountain grassland	3.700	10.000	606.000
Deciduous oak, big sagebrush	12.200	23.333	3420.000
Aspen	3.633	7.000	824.000
Spruce fir, Douglas fir, mixed conifer	3.233	7.667	601.000
Juniper	3.567	3.333	1622.000
Pinyon juniper	3.633	7.000	734.000
Ponderosa pine	12.200	17.333	2292.000
Overall average	7.005	10.535	1289.366

*Adapted from Theobald *et al.*, 2003 and Romme *et al.*, 2001

Vegetation data in the 100 meter zone surrounding the home was then classified into actual wildfire danger levels where: 0 represented no danger, 1 little danger, 2 moderate danger, 3 high danger, and 4 extremely high danger.

The next layer of data was slope, computed from the USGS Digital Elevation Model (30 m) (USGS, 2001). The steeper the slope, the faster the rate of wildfire spread. Therefore, homes on steep slopes face higher wildfire hazard than those on flat slopes. The slope variable was calculated for each home as an average across the 100 meter zone.

The final layer depicted locations (mapped as wildfire perimeter polygons) of wildfires that occurred in the year 2000, one year prior to survey data collection, in the Western United States[4]. All wildfires in Colorado and bordering states were included to determine the closest wildfires. Using GIS, the closest wildfires included the Bobcat Gulch and the High Meadow wildfire, both in Colorado. The High Meadow wildfire burned 10,500 acres and destroyed 51 homes in the Denver area. The Bobcat Gulch wildfire burned 10,600 acres and destroyed 22 homes in the Fort Collins–

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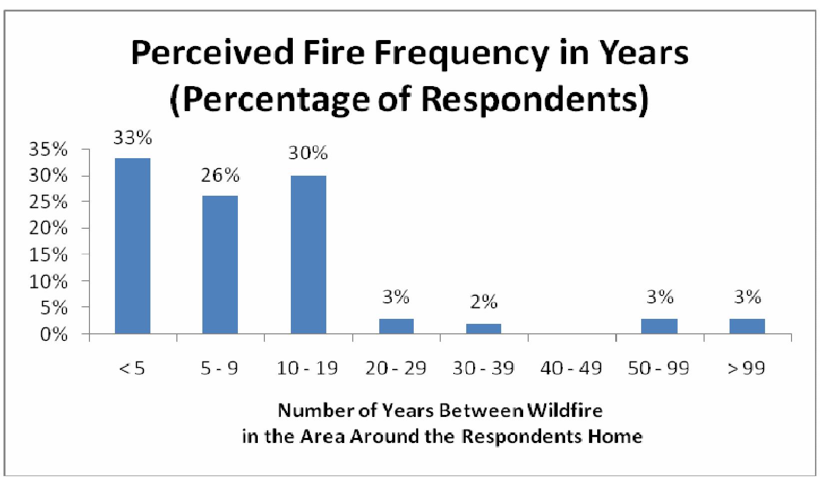
3 "Flame length (ft) is influenced by fuel model, fuel moisture, slope, and wind. Flame length is often used as a general descriptor of wildfire intensity and difficulty of suppression: a flame length of four feet is considered the upper limit for hand crews (Romme *et al.*, 2001)"

Masonville area. A proximity analysis was conducted by measuring the distance from the homepoint to the nearest edge of the wildfires. None of the respondents homes had been in a wildfire. The closest home to a wildfire was approximately 2 km from the perimeter of the Bobcat Gulch wildfire while the furthest was 83 km.

3. Results

Perceived and actual wildfire danger and WTP results were very insightful. Survey participants were asked how frequently fire occurred in their area and only 16% were unsure. Those that reported intervals believed that wildfire occurred frequently, with 92% believing wildfires occur at least once every 29 years (Figure 1). This concurs with actual wildfire figures of Veblen *et al.* (2000) and Brown *et al.* (1999), who reported the actual wildfire frequency average in these areas to also be at least once every 29 years.

Figure 1: Respondents Perceived Wildfire Frequency in the Area around their Homes



In the 100 meter vegetation zone surrounding their home, 30% of participants believed the chance of a wildfire was low, 29% believed the danger was moderate, and 41% believed the danger

4 Since the survey was completed in early 2001, focus was on wildfires that occurred in the previous year, 2000.

was high. None of the respondents believed wildfire would not occur in the zone.   The perceived wildfire danger level was then compared to the measured danger level for the 100 meter zone. It was found that the percentage of properties perceived to be in a high danger area far exceeded the measured percentage (Table 2).

Table 2. Comparison of actual and perceived wildfire danger level for the area surrounding respondents homes.

Wildfire Danger Level	'Actual' Wildfire Danger of Area Surrounding the Home (% of respondents)	'Perceived' Wildfire Danger of Area Surrounding the Home (% of respondents)
None	5%	0%
Low	33%	30%
Moderate	40%	29%
High	22%	41%

While all respondents perceived some level of wildfire danger in the 100 m zone surrounding their home, only 64% perceived their house was in danger of wildfire. In addition, 32% of homes had a 30 meter defensible space and, of these, 70% believed their home was still in danger of wildfire. Having this defensible space significantly lessens the chances that the home would burn in a wildfire; however, most respondents seemed not to believe their homes risk from wildfire was completely alleviated (Table 3).

Table 3. The proportion of respondents that have a defensible space, and believe their home is in danger of wildfire, is compared to those who do not.

	Believes Home is in Danger of Wildfire (64%)	Does Not Believe Home is in Danger of Wildfire (36%)
Has Defensible Space (32%)	70% of those with defensible space	30% of those with defensible space
Does Not Have Defensible Space (68%)	62% of those without defensible space	38% of those without defensible space

Of those respondents that did not have a defensible space, 62% believed their home was in danger of wildfire, slightly less than those with defensible space. When evaluating the actual wildfire danger in the area surrounding respondents' homes without defensible space, not only did all of these respondents have some wildfire danger risk, but a more in-depth spatial analysis revealed that 90% lived in a medium or high wildfire danger area. These respondents were aware of the wildfire danger in their area, but as can be seen, some assume incorrectly that their home is not in danger.

WTP for wildfire prevention was estimated from the survey results using a logit regression model. The results showed that the bid variable was negative and significant at the 95% level, indicating that more people are WTP for wildfire prevention at lower bid amounts than higher bid amounts.

Logit results are as follows (with P-values in parenthesis):

WTP for Wildfire Prevention (yes, no)
= 1.0975 – 0.0028 Bid Amount
(0.000) (0.012)

WTP was calculated from the logit results using the formulas by Hanemann (1984, 1989) and Park *et al.* (1991). It was determined that Colorado respondents living in the WUI were willing to pay $443 in taxes annually[5] for wildfire prevention activities in their immediate area.

To test the hypothesis that WTP would be affected by perceived and actual wildfire danger variables, these variables were added to the original model. It was found that both perceived and actual wildfire variables had an effect on WTP. Because interpretation of the coefficient in a logit model is not straightforward, coefficients were converted into WTP values by dividing the bid amounts by the absolute value of the bid coefficient (Cameron 1988; Richardson 2002). Results

[5] $443 mean, $493 median and 90% confidence level between $409 and $586.

show that if they believe their home is in danger of wildfire (perceived risk), they would be willing-to-pay $346.61 more each year for wildfire prevention in their area. If their perceived calculations of the frequency of wildfires were increasing in their area, they would be willing-to-pay $5.03 more annually. Respondents who maintained a defensible space around their home would be willing-to-pay $478.69 more each year in their taxes for wildfire prevention compared to those who did not. In addition, actual wildfire danger from vegetation in the 100 meter zone around a home increased the WTP by $133.50. The other actual wildfire danger variables (distance to wildfire and slope) were not significant (Table 4).

Table 4: WTP for Wildfire Prevention, Accounting for Perceived and Actual Wildfire Risk: Logit Regression Results. Significant variables indicated in bold.

Variable	**Wildfire Prevention**	**Wildfire Prevention WTP**
C	-2.01 (0.40)	
Bid Amount	**-0.00 (0.05)**	
Perceived Wildfire Danger	**1.47 (0.07)**	**$346.61**
Perceived Wildfire Frequency	**0.02 (0.15)**	**$5.03**
Proper Defensible Space Around the Home	**2.03 (0.05)**	**$478.69**
Actual Wildfire Danger in 100 Meter Buffer Zone Around Home	**0.56 (0.07)**	**$133.50**
Distance to Wildfires from Previous Year	-2.64E-06 (0.89)	$0.00
Slope in Vicinity of Home Location	-0.05 (0.50)	$13.88

4. Discussion and Conclusions

The cost of suppression and initial attack of wildfires in the United States has increased significantly over the last 20 years. One way to reduce the risk of high-intensity wildfires, and also decrease the cost of wildfire suppression to United States taxpayers, is to reduce current fuel loads in forests by thinning. In this study, surveys were used to determine if people living in the Colorado wildland urban interface (WUI) considered their home at risk from wildfire, and if they had a willingness-to-pay (WTP) for wildfire prevention methods such as thinning. Spatial analysis of surrounding vegetation, slope, and previous wildfire locations was used to determine the actual wildfire danger for each respondent's home. This allowed the comparison of actual and perceived risk of wildfire.

Colorado residents in the WUI appeared to be well aware of the wildfire danger in their area. On average, residents believed the wildfire danger in their immediate area was either higher or the same as the actual wildfire danger. This was especially true for the high wildfire danger classes, where 41% believe their area had a high wildfire risk of burning while only 22% of homes were actually were at high danger. None of the respondents believed their area was not in danger of wildfire, but 5% actually had no wildfire danger.

Some respondents are active in trying to prevent their home from burning in a wildfire by creating a defensible space. It is interesting to note that 64% of people believed their home was in danger of wildfire, but only 32% of homes had a defensible space. Perhaps more people can be encouraged to create defensible space around their homes if the lands surrounding their homes had lower fuel loads, resulting in lower intensity wildfires, as this would also reduce the chances of their homes burning even with defensible space as well as a quicker recovery time for larger trees.

On average, respondents were willing to pay $443 annually in their taxes for wildfire prevention in their immediate area. People who perceive their home is in danger of wildfire, or that wildfire occurs more frequently in their area, have a higher WTP. People that maintained a defensible space around their home were significantly more WTP than those that did not have defensible space. This may reflect the time and effort they put in to create the defensible space.

Actual wildfire danger of the 100 meter vegetative zone surrounding their homes also had a significant effect on WTP. This result shows that people are well aware of the wildfire danger in their area, even though, as shown previously, their actual wildfire danger may be slightly less than they perceive. This perspective means that people are more likely to take precautions to protect their homes.

Other variables describing actual wildfire danger, such as the distance to last years wildfires and slope of the land, did not affect WTP. Wildfire the previous year, in their immediate area, might lower the current wildfire danger as there would be less underbrush to fuel a new wildfire. However, since the closest wildfire was 2145 meters (well over one mile) from one of the homes, perhaps this was not something they took into account. Slope also did not have an effect, but people in the WUI often build homes on steep slopes Steep slopes do provide an opportunity for wildfire to travel quickly up a hill, but they also can provide a homeowner with a better view. Perhaps people are not aware that steep slopes can increase their wildfire danger or perhaps the risk is less than the enjoyment of the view.

The hypothesis, that willingness-to-pay for wildfire prevention is linked to both perceived and actual wildfire danger, was found to be true. People's awareness of the danger from wildfire is a positive outcome, and their willingness-to-pay to reduce the danger demonstrates a proactive attitude to the problem. This also supports implementation of targeted cost recovery for wildfire prevention based on the measured risk of wildfire for individual properties.

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