Social disorder, accidents, and municipal wildfires

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Abstract:
Societal safeguards, established by those who have shared perceptions of the importance of safety and taking preventative measures, reduce the incidence of accidents that harm people and damage property. These safeguards prevent or discourage community members from partaking in careless behaviors that often lead to accidents. Wildland urban interface communities that recognize the importance of safety and taking preventive measures are likely to have a lower rate of accidental wildfire. Research has established a strong link between a positive safety culture and a reduction in accidents. This paper tests whether the lack of societal safeguards results in higher rates of accidental wildfires by modeling unintentional human caused wildfires as a function of constructed 'Broken Window' indices. Abandoned buildings and unkempt infrastructure identify areas with social disorder, where individuals are more likely to partake in careless behaviors that result in frequent accidents. The results from this analysis suggest that social collaboration and crime prevention programs as well as wildfire safety programs may be effective tools in preventing accidental wildfire ignitions and damage.

Additional Keywords: accidental fire; broken windows; norms; social disorder; wildfire

Introduction

The 'Broken Window' theory, presented by Wilson and Kelling, discusses the effect that dilapidated buildings and infrastructure (e.g., sidewalks, roads, bridges, and other outdoor public spaces) along with disorderly behavior (e.g., minor offenses such as defacing public property or littering) have on more serious criminal behavior (Wilson 1982). The term broken window originates from the idea that if a building has one broken window that goes unrepaired, eventually all the windows will be broken. The broken window is a signal to others that there is little or no concern about destructive behavior directed towards the building and there are no consequences for breaking another window or engaging in other destructive behavior. That is, broken windows affect the perception of whether one will be punished for a crime (Lochner 2007), and signal that there is neighborhood apathy or a lack of collective efficacy (the willingness of a neighborhood to band together for the common good) (Sampson 1997). 'Broken windows' is a reference to both individuals visibly breaking social norms and the visual evidence

left from social norms being broken.[1] The theory conforms to Becker's economic model of crime, which proposes that the 'cost' of committing a crime (e.g., fines, fees, or jail time) influences the probability that a would-be criminal engages in illegal behavior (Becker 1968). The implication is that lower arrest and conviction rates, as a result of neighborhood apathy, are associated with lower costs of committing a crime.

In addition to conforming to Becker's work, the idea that social disorder (i.e., norm violating behavior) results in more social disorder is substantiated by a series of experiments performed by Keizer et al. (2008). One of these experiments showed that individuals were far more likely (69 % vs. 33 %) to litter in the presence of increased social disorder (in the form of graffiti) than without the disorder, ceteris paribus. Other, seemingly similar, experiments provided analogous results where individuals violated rules and even police ordinances, such as those that could prevent accidental fires, when in the presence of increased social disorder. The study concluded that "as a certain norm-violating behavior becomes more common, it will negatively influence conformity to other norms and rules" (Keizer et al. 2008). This can be directly applied to fire safe behavior, which relies on conscientious individuals conforming to rules and norms (Butry et al. 2010; Prestemon et al. 2010) that reduce the risk of a fire or heat source spreading beyond its intended use. Thus, visible evidence of norm violating behavior (i.e., 'broken windows' or social disorder) encourages further deviation from the norms and rules that prevent accidental fires.

To further support the connection between 'broken windows' and fire, research has shown that Michigan arson behavior is consistent with the 'broken window' theory as is wildland arson in Florida (Prestemon and Butry 2005; Thomas et al. 2010). 'Broken windows' signal a lower cost of crime that increases criminal behavior such as arson. Arson incidents follow similar trends to that of accidental fires, both in theory (Thomas et al. 2010) and in trend data as seen in Figure 1. Careless fire behavior, such as disregarding fire restrictions or lighting untamed camp fires, and arson might be influenced by similar phenomenon. Thus, in addition to signaling a lower cost of crime, 'broken windows' might signal a lower cost of careless behavior due to a lack of enforcement and social pressure while also signaling the presence of neighborhood apathy. This lack of concern for one's neighbors results in a lack of shared perceptions in the importance of safety and taking preventative measures—behavior that often leads to accidents, such as those that result in wildfires.

Although 'broken windows' have been connected with crimes such as arson, there is a limited amount of literature that connects accidents in a community, such as those that result in wildfires, with 'broken windows.' A significant proportion of the literature on accidents focuses on occupational accidents. Approximately 80 % to 90 % of these accidents are thought to be due to human error (Heinrich et al. 1980; Hale and Glendon 1987; Salminen and Tallberg 1996); thus, the vast majority involve human behavior and not unforeseen acts of nature. Research on occupational accidents has concluded that the best safety and health programs have an established safety culture (Occupational Safety and Health Administration), which includes "shared perceptions of the importance of safety and… confidence in the efficacy of preventive measures" (Health and Safety Commission 1993). Research has further found a significant correlation between reduced accidents and positive safety culture/safety climate in the workplace (Hofmann and Stetzer 1996; Oliver et al 2002; Gillen et al 2002; Hemingway and Smith 1999;

[1] Although the behavior that is not favored (i.e., the destructive behavior) can often become the norm, for the sake of being clear and concise, this paper will treat the preferred behavior as the norm.

Clarke 2006; Bjerkan 2010; Tomas 1999; Varonen 2000; Lucas 1992).[2] A positive safety culture/climate might be described as an environment where people conform to norms and rules regarding safety. It is plausible, therefore, that communities that recognize the importance of safety and taking preventive measures are also likely to have a lower rate of accidents. In 2009, there were an estimated 6.8 million injuries[3] resulting in 2923 deaths that occurred at personal residences (U.S. Consumer Product Safety Commission 2009). It is likely that these accidents have similar causes to occupational accidents (i.e., human behavior); thus, the effect of careless behavior at home is significant. Many of these injuries may have been prevented by taking safety measures. In regards to accidental fires, the focus of this paper, it is estimated that 55 % of wildfires between 2002 and 2007 were human caused unintentional fires[4] and, although these accidents are not always related to occupational accidents, they are likely related to careless behavior influenced by a lack of shared perceptions on the importance of safety and taking preventive measures.

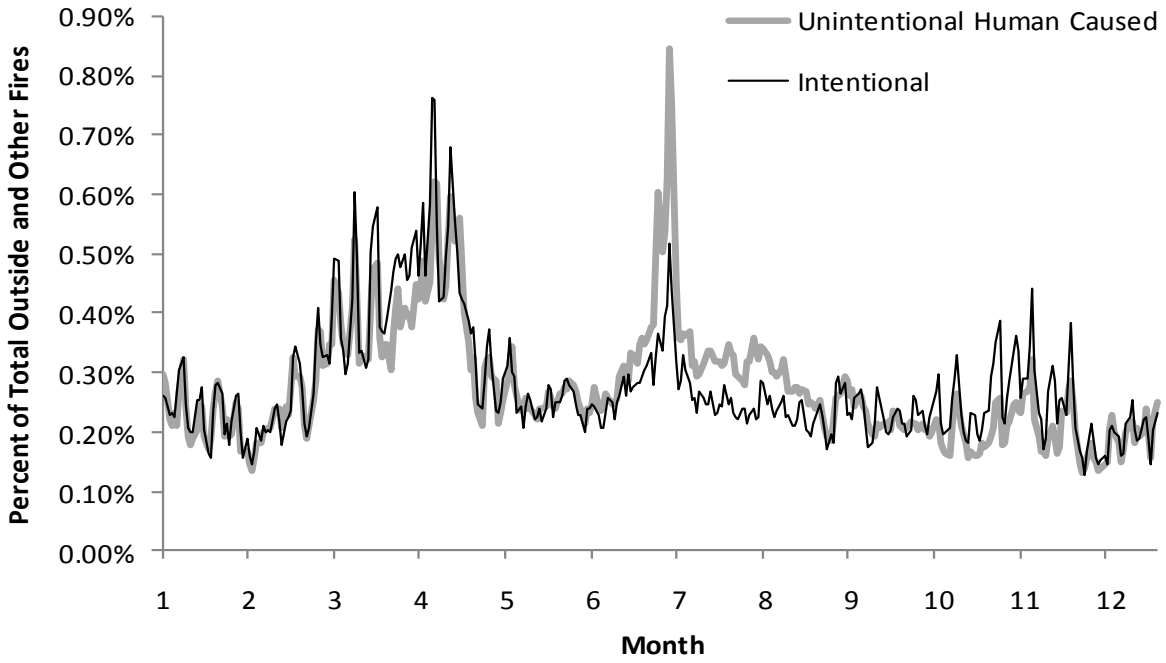

Figure 1: National Daily Percent of Outside Human Caused Fires by Intention Averaged by Day of Week, 2002-2006 (Note: Outside fires includes all fires that are not structural or vehicle fires)

Since 80 % of wildfires are human caused (intentional and unintentional) and an average of 117 000 wildfires occur annually (Thomas and Butry 2012), it is important for decision makers and land managers that invest in mitigation techniques and strategies to minimize the cost and

[2] Safety climate is often used interchangeably with safety culture.
[3] These injuries are limited to those associated with consumer products.
[4] Estimates from the National Fire Incident Reporting System adjusted using NFPA survey data

losses of wildfire to identify behavior that is associated with increased rates of wildfire ignition. Some human caused fires (all types) are intentional; however, approximately 89 % are accidental,[5] caused by carelessness or inattention (U.S. Fire Administration 2000). A contribution of this paper is to test whether the presence of social disorder results in accidental wildfires by modeling unintentional human caused wildfires as a function of constructed 'broken window' indices. Specific wildfire prevention efforts that modify behavior might then be targeted to areas where careless behavior is prevalent and create a positive safety culture.

A culture of safety can increase the costs of careless behavior through enforcement of safety protocols (i.e., punishment for not following safety procedures) and social pressure (i.e., being reprimanded by peers) along with reducing apathy for one's neighbors. A positive safety culture includes a shared set of attitudes, ideas, and values (Cox and Cox 1991; International Safety Advisory Group 1991; Pidgeon 1991; Cheyne et al. 1998; Health and Safety Commission 1993); thus, in addition to increasing the cost of careless behavior, it reduces the costs of taking preventative measures by providing knowledge of safety protocols (i.e., dissemination of safety information). Well organized communities, for example, discuss and encourage safe practices that diminish neighborhood apathy at community/neighborhood meetings. Neighborhoods with homeowner associations, for example, may distribute information on safe practices. 'Broken window' communities are less likely to have this type of infrastructure put in place. Furthermore, the social disorder that tends to be present in 'broken window' communities has a negative influence on individuals conforming to norms and rules, as shown by Keizer et al. (Keizer 2008). An example of a successful national program to improve fire safety culture is the campaign featuring Smokey Bear, who is now one of America's most recognized characters. This campaign has successfully impacted generations of Americans concerning their role in wildfire prevention (U.S. Forest Service). Similar efforts might be concentrated at the local level to communities that are more prone to accidents due to careless behavior.

Theory

Becker's economic model of crime proposes that the "cost" of committing a crime influences the probability that a would-be criminal engages in illegal behavior (Becker 1968). The implication is that lower arrest and conviction rates are associated with lower costs of committing a crime. Becker's expected utility function for a criminal offense provides an excellent model to use in order to form an expected utility function for careless behavior. We can model the utility of careless behavior as the following:

$$EU_j = p_j U_j(Y_j - f_j) + (1 - p_j) U_j(Y_j)$$

Where

EU_j = expected utility for careless behavior for individual *j*

p_j = probability of individual *j* receiving negative consequences for careless behavior

U_j = utility function of individual *j*

Y_j = monetary and/or psychological benefits of careless behavior for individual *j*

f_j = negative consequences to individual *j* for careless behavior

[5] Calculated using National Fire Incident Reporting System (NFIRS) data between 2002 and 2006

In terms of careless fire behavior, benefits *Y* might include items such as excitement from a bonfire, avoiding the costs of proper waste disposal, or avoiding the costs of repairing sparking machinery. Negative consequences might include being socially reprimanded (i.e., social pressure), being held liable for damages, or receiving fines, fees, or imprisonment from authorities. Areas with 'broken windows' signal that the probability of receiving negative consequences (p_j) is lower than in other non-'broken window' areas; therefore, the expected utility for careless behavior (EU_j) is higher in these areas. 'Broken windows' also signal the presence of social disorder, where the acquisition of safety information is likely to be an additional cost of avoiding careless behavior. 'Broken window' areas might also contain lower values at risk, resulting in lower safety standards. Safety can be incorporated into the model as *s*:

$$EU_{j,s} = p_{j,s}U_j(Y_{j,s} - f_{j,s} - c_s) + (1 - p_{j,s})U_j(Y_{j,s} - c_s)$$

Where
$EU_{j,s}$ = expected utility for careless behavior for individual *j* and safety level *s*
$p_{j,s}$ = probability of individual *j* receiving negative consequences for careless behavior with safety level *s*
U_j = utility function of individual *j*
$Y_{j,s}$ = monetary and/or psychological benefits of careless behavior for individual *j* at safety level *s*
$f_{j,s}$ = negative consequences to individual *j* for careless behavior with safety level *s*
c_s = cost of safety precaution at level *s*

An effective increase in *s* can decrease $p_{j,s}$, $f_{j,s}$, and/or $Y_{j,s}$; that is, as more safety measures are employed the probability of negative consequences, the severity of the negative consequences, and/or the income from the behavior decreases.

Following from this model, an individual that does not perceive any possible negative consequences is unlikely to take any safety precautions. Individuals in communities that have a lack of shared perceptions on the importance of safety and taking preventive measures (e.g., 'broken window' communities), as well as those that have lower values at risk, are also likely to have a low safety level, where there is little or no investment in preventive measures. For example, previous research has linked 'broken windows' with automotive accidents (Giacopassi 2000). These communities can have a safety level below the optimal amount because their perceived level of direct negative consequences (e.g., damage caused by an uncontrolled fire) is lower than the actual level. Individuals in safety conscious communities, however, implement higher safety levels closer to the optimal amount because their perceived level of direct negative consequences is closer to the actual level.

Individuals in 'broken window' communities have a lower probability of negative consequences (p_j), both actual and perceived. Neighborhood apathy in these areas results in misperceived direct negative consequences as well as a lower probability of receiving indirect negative consequences (e.g., punishment). Along with lower probabilities of negative consequences, many individuals in these areas have lower incomes (Wilson and Kelling 1982; Sampson et al. 1997) and, thus, lower values at risk, which has been shown to impact accident rates (Nersesian 1985). Additionally, it is likely that these areas have fewer community resources dedicated to implementing safety because of neighborhood apathy, a key component of the

Broken Windows theory (Wilson and Kelling 1982; Sampson et al. 1997); therefore, an individual must expend more personal resources to achieve a certain level of safety than an individual in a non-'broken window' community. For example, a 'broken window' community may be less likely to have bulk trash pickup making it more likely for someone to burn their yard waste. Thus, 'broken window' communities have both an actual and perceived lower probability of negative consequences (p_j) and a higher individual cost to implement safety precautions (c_s).

This paper tests whether 'broken window' variables, which reflect neighborhood apathy and a decreased probability of receiving negative consequences, result in accidental wildfires. That is, it tests whether 'broken window' variables (i.e., visible evidence of norm violating behavior) result in neighborhoods that have a lower level of fire safety caused by decreased indirect consequences (e.g., punishment), perceived decreased direct consequences (e.g., damage caused by an uncontrolled fire), and increased costs to implement safety precautions (e.g., identifying safe practices) compared to non-'broken window' communities. If this is correct, then social collaboration and crime prevention programs, as well as wildfire safety programs may be effective tools in preventing accidental wildfire ignitions and damage in these areas. To test this theory, this paper models unintentional human caused wildfires as a function of constructed 'broken window' indices, which are defined below.

Model

This analysis uses a Zero-Inflated Poisson (ZIP) model to regress the count of unintentional human caused wildfire ignitions on 'broken window' variables. The wildfire data is aggregated ignition counts by county and spans from 2001 to 2005 for the state of Michigan. Not all states have complete NFIRS reporting; however, Michigan requires fire departments to report to NFIRS by law. Since many of the variables in the model are lagged one year, the regression includes observations from 2002 to 2005. The ZIP model allows the model to account for a hurdle process, where the count of wildfire is either (1) always zero or (2) sometimes zero and sometimes positive. An example of wildfire counts always being zero might be in highly urbanized counties where there is no wildland fuel. The model is estimated with the following equations:

Equation 1

$$\Pr(A_i = 0) = \Pr(d_i = 0) + \big(1 - \Pr(d_i = 0)\big)e^{-\lambda_i}$$

Equation 2

$$\Pr(A_i = a_i) = \frac{\big(1 - \Pr(d_i = 0)\big)e^{-\lambda_i}\lambda_i^{a_i}}{a_i!}, a_i = 0, 1, 2, \dots$$

Where
A = count of wildfire
i = index of the observations by county and year combinations
d = an indicator variable identifying whether the count is (1) always zero or (2) sometimes zero and sometimes positive

The probability of the count always being zero is a function of inflation factors z and parameters γ, where $\Pr(d_i = 0) = F(z_i, \gamma)$. The expected number of wildfires, given that it is not always zero, is $_i = e^{\ \kappa x_i}$, where the number of wildfires are a function of covariates x and parameters . The

probability of wildfire always being zero is estimated using the logit specification, where $F(z_i, \gamma_k) = (1 + e^{-\gamma z_i})^{-1}$. A log-likelihood function is maximized to estimate the ZIP model's parameters (Stata 2007).

Data

The source for the wildfire data is the National Fire Incident Reporting System (NFIRS). For the purpose of this paper, a fire was considered a human caused unintentional wildfire if it involved wildland fuel and was either classified as unintentional or a failure of equipment or heat source. The population of Michigan is concentrated toward the southern part of the state where most of the major urban areas are located; therefore, there are more human caused fires in this area as seen in Figure 2. Much of the upper and northern lower peninsulas of Michigan is national forest.

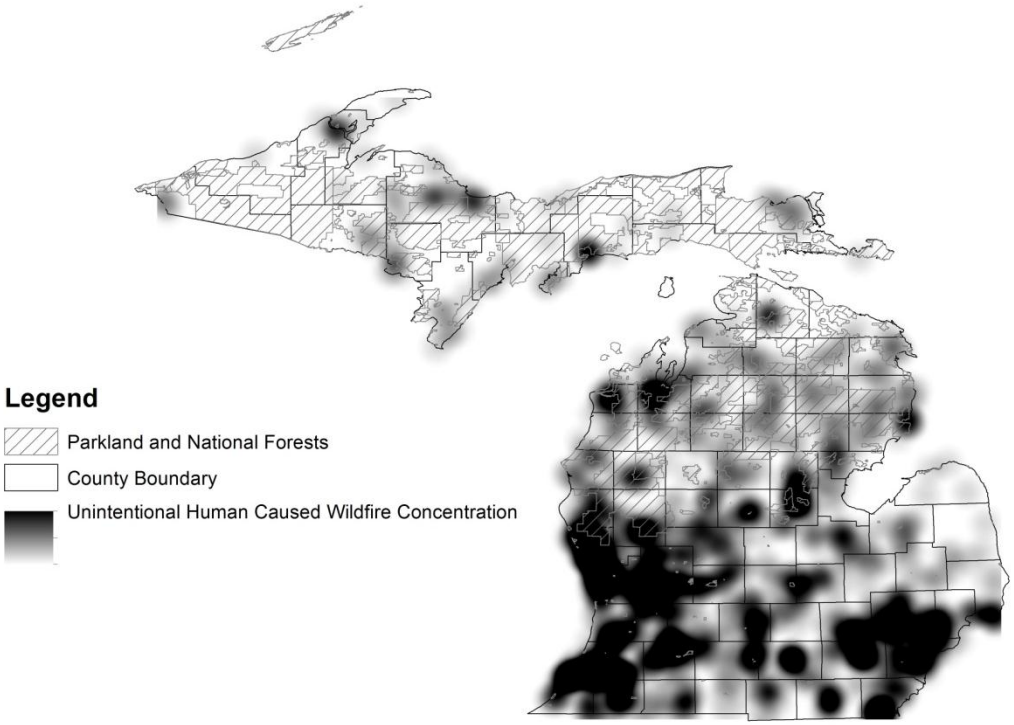

Figure 2. Unintentional Human Caused Wildfire Density Map of Michigan using NFIRS Data

There are a total of 331 observations used in the analysis. Each observation represents the total number of human caused unintentional wildfires occurring in a county. On average, there were 232 human caused unintentional wildfires annually reported in NFIRS for the entire state of Michigan between 2002 and 2005. As seen in Table 1, among the county observations between 2002 and 2005 there were a maximum of 30 unintentional human caused wildfires a year and a minimum of 0. The total number of human caused unintentional wildfires for the analyzed data set is 929. As seen in Table 2, approximately 9.8 % or 91 fires were caused by operating

equipment. Another 29.1 % or 270 fires were caused by hot embers or ash. Open flames and smoking materials caused 23 % or 214 fires.

Table 1: Unintentional Human Caused Wildfires

Year	Total	Average	Minimum	Maximum	Counties with zero
2002	136	1.6	0	10	29
2003	338	4.1	0	30	18
2004	179	2.2	0	10	27
2005	276	3.3	0	23	12
Total	929	2.8	0	30	86

Table 2: Unintentional Human Caused Wildfires by Heat Source, 2002-2005

Heat Source	Incidents	Percent
Operating Equipment	91	9.8%
Hot Ember or Ash	270	29.1%
Other Hot or Smoldering Object	45	4.8%
Explosives, Fireworks	41	4.4%
Cigarette, Pipe, or Cigar	23	2.5%
Match or Cigarette Lighter	68	7.3%
Other Open Flame or Smoking Materials	123	13.2%
Chemical	9	1.0%
Other Heat Source	59	6.4%
Undetermined	200	21.5%
TOTAL	929	100.0%

The NFIRS system is a voluntary system; therefore, there are some reporting limitations. Michigan state law requires fire departments to report to NFIRS, however, many fire departments are behind schedule in providing data for the system. Since it is not known if gaps in the data are due to lack of reporting or a lack of fire activity, a metric was developed to measure reporting by county. It is the proportion of months per year that a fire department reported fire incidents averaged per county per year. The average fire department reported 9 to 10 months of the year. Fortunately, by including a reporting variable in the model the ZIP model corrects for this type of problem directly in empirical estimation.

This paper models human caused unintentional wildfires on measures of the costs of hazardous fire behavior (e.g., disregarding fire ordinances), opportunity costs (i.e., other non-hazardous opportunities), personal and professional fire inducing activity, and social disorder. The model includes year indicator variables to account for state-wide trends such as steady changes in levels of fire prevention efforts and fire awareness programs. The following data are included in the model:

Costs of hazardous fire behavior
Precipitation: Annual number of days with precipitation. Source: National Oceanic and Atmospheric Administration (National Oceanic and Atmospheric Administration 2007)
Temperature: Mean annual high temperature and number of days above 64 degrees. Source: National Oceanic and Atmospheric Administration (National Oceanic and Atmospheric Administration 2007)
Police: Total number of officers by year. Source: Inter-University Consortium for Political and Social Research (U.S. Department of Justice 2003)

Opportunity costs
Population: Annual population. Source: Census Bureau (Population Division 2006)
Poverty Universe: Persons whom the Census Bureau determined to be in poverty. Source: Census Bureau (U.S. Census Bureau 2009)
Youth Population: Annual number of youth aged 15-21. (Studies have shown that youth participate in hazardous behavior more frequently than adults). Source: Census Bureau (Population Division 2008)
Fire fighters: The annual number of paid and volunteer fire fighters. Source: National Fire Incident Reporting System (Federal Emergency Management Agency 2006).

'Broken windows'
Disorder: Arrests for prostitution, vandalism, vagrancy, curfew violation, public drunkenness, drug possession and sale, and runaways. (Reported street crime data are not available.) Source Uniform Crime Reports (U.S. Department of Justice 2007)
Vacancy Rate: Number of units in the county that are deemed vacant; this number is then divided by the total number of units in the county. Source: United States Post Office and Census Bureau

Crime activity
Arrests: Arrests for Part I index crimes (homicide and manslaughter, robbery, rape, aggravated assault, burglary, larceny, motor vehicle theft, and arson). Source: Uniform Crime Reports (U.S. Department of Justice 2007)
Reported Crime: Reported Part I index crimes (homicide and manslaughter, robbery, rape, aggravated assault, burglary, larceny, motor vehicle theft, and arson). Source: Uniform Crime Reports (U.S. Department of Justice 2007)

Personal and occupational activity
Employed: Number of people employed. Source: Bureau of Labor Statistics (Bureau of Labor Statistics 2007)
Income: Household median income. Source: Census Bureau (Population Division 2008)

Fuel type

Deciduous forest: The proportion of land within the specified county that is "dominated by trees generally greater than 5 m tall, and greater than 20 % of total vegetation cover; additionally more than 75 % of the tree species shed foliage simultaneously in response to seasonal change." Source: Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Database.
Mixed forest: The proportion of land within the specified county that is "dominated by trees generally greater than 5 m tall, and greater than 20 % of total vegetation cover; additionally neither deciduous nor evergreen species are greater than 75 % of total tree cover." Source: Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Database.
Shrub- and scrub-land: The proportion of land within the specified county that is "dominated by shrubs; less than 5 m tall with shrub canopy typically greater than 20 % of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions." Source: Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Database.
Grassland and Herbaceous: The proportion of land within the specified county that is "dominated by grammanoid or herbaceous vegetation, generally greater than 80 % of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing." Source: Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Database.
Wildland Urban Interface: Total square miles of wildland urban interface. Source: Silvis Laboratories (2000).

The final set of regressors include the following: number of firefighters normalized by population, total square miles of grass and forest land, number of days with precipitation, number of days with temperature above 64 degrees (temperature at which physically inactive people begin to shiver; see Canadian Center for Occupational Health and Safety 2007), disorder, vacancy rate, arrests normalized by reported crimes (clearance rate), disorder normalized by police, number of officers normalized by population, vacancy rate normalized by youth population, vacancy rate normalized by population, number of people in poverty normalized by population, household median income, number of people employed normalized by population, and year dummy variables.

The number of days with temperature above 64 degrees is used as a proxy for when the temperature is in a range where it is comfortable to remain outdoors. Fire fighters normalized by population proxies for efforts to prevent accidental ignitions. Disorder, vacancy rate, population, income, poverty, crime, employment, and police are lagged 1 year to avoid possible simultaneity bias with the dependent variable. Arrests normalized by reported crime proxies for police success, which is expected to be negatively related to accidental wildfires. A surveillance effect is accounted for by normalizing vacancy rates with population. Vacancy rate is also normalized by youth population to account for juveniles. Disorder and the vacancy rate are proxies for social and physical disorder ('broken windows'). Income and the percent of the population that is employed proxy for personal activity and activity in the workplace, respectively, while poverty normalized by population represents income effects on behavior, therefore controlling for individuals with lower values at risk. As personal activity and workplace activity increase, the number of opportunities for accidental fires increases; therefore, one would expect an increase in wildfires from an increase in activity.

The inflate variables include the total square miles of wildland-urban interface, total square miles of forest land, total square miles of grassland, total population, a measure of fire department reporting, arrests for index crimes, and arrests for index crimes normalized by police. The inflation procedure estimates the probability of zero accidental wildfires. Since accidental wildfires require the presence of people and wildland, population is included in the inflate statement as is the square miles of forestland, grassland, and wildland-urban interface. Crime is normalized by police to account for police success.

Results

The model of human-caused unintentional wildfires is highly significant as seen in Table 3. Precipitation and temperature are statistically significant at the 1 % level with temperature being positively correlated and precipitation being negatively correlated, as would be expected. Disorder, disorder normalized by police, and vacancy normalized by youth population are statistically significant at the 10 %, 5 % and 1 % levels and positively correlated with unintentional wildfire, as expected based on the Broken Windows theory. Vacancy normalized by population is negatively correlated with wildfire while vacancy normalized by the youth population is positively correlated. Poverty normalized by population, income, and employed persons normalized by population are all positively correlated with wildfires, also as hypothesized in this study.

A Vuong test is used to test if the ZIP specification is preferred over the Poisson; the Vuong test statistic is $z = 2.45$ with $p = 0.0072$, which supports that the ZIP specification is preferred over the Poisson. Among the zero-inflation factors, population was statistically significant at the 5 % level. Since people (and their machines) are the sole source of accidental wildfires, it is logical that as there are fewer people and more wildland, there would be fewer accidental wildfires.

Both of the 'broken window' variables that we tested, vacancy rate and disorder (previous year's arrests for prostitution, vandalism, vagrancy, curfew violation, public drunkenness, drug possession and sale, and runaways) are positively correlated with human-caused unintentional wildfires at the 10 % statistically significant level. The elasticity of the vacancy rate is 0.18, meaning that a 1 % increase in the vacancy rate results in a 0.18 % increase in accidental wildfires, assuming all other regressors remain the same. (All elasticities are evaluated at the mean value of the covariates.) The elasticity of disorder is 0.02, meaning that a 1 % increase in disorder results in a 0.02 % increase in accidental wildfires. However, a 20 % decrease in the vacancies is estimated to result in a 1.3 % decline in accidental wildfires, as seen in Table 4. Likewise, a 20 % decrease in disorder would result in a 5 % decrease in accidental wildfires. Table 4 contains a number of other variables to give some context to this impact. Efforts to reduce wildfires by increasing police by 20 % are estimated to result in a 6.9 % decline in accidental wildfires as seen in Table 5.

Table 3: Results of Zero Inflated Poisson Regression of Human Caused Unintentional Wildfires

Variable	P>|z|	Elasticity	Standard Error
Square miles of Grass and Forest Land	0.000	4.24E-01	8.08E-02
Days with temperature above 64 degrees	0.000	2.41E+00	4.62E-01
Days with precipitation	0.000	-2.22E+00	2.48E-01
Vacancy rate	0.005	1.75E-01	6.20E-02
Disorder	0.087	2.16E-02	1.26E-02
Arrest rate	0.673	-4.51E-02	1.07E-01
Disorder normalized by police officers	0.010	2.62E-01	1.02E-01
Fire fighters normalized by population	0.200	-5.94E-02	4.63E-02
Police normalized by population	0.013	-2.05E-01	8.23E-02
Vacancy normalized by population	0.003	-9.16E-01	3.06E-01
Vacancy normalized by youth population	0.005	8.08E-01	2.87E-01
Poverty normalized by population	0.024	6.46E-01	2.85E-01
Household median income	0.000	1.34E+00	3.59E-01
Employed persons normalized by population	0.000	2.58E+00	5.91E-01
Year 2002	0.000	-1.55E-01	3.23E-02
Year 2003	0.000	1.26E-01	2.65E-02
Year 2004	0.999	2.93E-05	2.57E-02
Zero-Inflation Factors			
Square miles of WUI	0.147	-2.71E-05	1.20E-04
Square miles of forest	0.136	-5.74E-06	3.00E-05
Square miles of grass	0.663	7.01E-06	3.00E-05
Population	0.034	2.30E-04	1.05E-03
Reporting	0.311	2.08E-05	1.00E-04
Arrests for index crimes	0.100	-1.18E-04	5.50E-04
Arrests for index crimes normalized by police officers	0.391	9.35E-06	5.00E-05

Table 4: The Number and Percent Change in Accidental Wildfires for the State During the Study Period with a Hypothetical -20% and -10% Change in Count Factors

	-20%		-10%	
	Incidents	Percent	Incidents	Percent
Days with temperature above 64 degrees	-362	-38.9%	-198	-21.3%
Days with precipitation	504	54.3%	233	25.0%
Vacancies*	-12	-1.3%	1	0.1%
Disorder**	-47	-5.0%	-17	-1.8%
Arrest rate	22	2.4%	18	1.9%
Police***	124	13.4%	63	6.8%
Poverty	-96	-10.3%	-43	-4.6%
Household median income	-225	-24.3%	-115	-12.4%
Employed persons	-375	-40.3%	-206	-22.2%
All Economic Variables	-458	-49.3%	-264	-28.4%

* This variable impacts three regressors: vacancy rate, vacancy normalized by population, and vacancy normalized by youth population

** This variable impacts two regressors: disorder and disorder normalized by police officers

*** This variable impacts two regressors: disorder normalized by police officers and police normalized by population

Table 5: The Number and Percent Change in Accidental Wildfires for the State During the Study Period with a Hypothetical +10% and +20% Change in Factors

	+10%		+20%	
	Incidents	Percent	Incidents	Percent
Days with temperature above 64 degrees	288	31.0%	642	69.1%
Days with precipitation	-163	-17.5%	-306	-32.9%
Vacancies*	27	2.9%	41	4.4%
Disorder**	46	4.9%	79	8.5%
Arrest rate	10	1.0%	6	0.6%
Police***	-28	-3.0%	-64	-6.9%
Poverty	74	8.0%	139	15.0%
Household median income	164	17.6%	339	36.5%
Employed persons	301	32.4%	678	73.0%
All Economic Variables	413	44.5%	990	106.6%

* This variable impacts three regressors: vacancy rate, vacancy normalized by population, and vacancy normalized by youth population

** This variable impacts two regressors: disorder and disorder normalized by police officers

*** This variable impacts two regressors: disorder normalized by police officers and police normalized by population

Weather has a significant impact on the number of human-caused unintentional wildfires, as would be expected. Weather patterns have a significant effect on human behavior and fire behavior. Days of precipitation and days with temperature above 64 degrees are both statistically

significant indicators of accidental fire probability. The reporting variable is not significant, meaning that under-reporting does not provide any systematic bias. Grass and forestland are associated with increased occurrence of wildfire. This variable may reflect both ignitability of wildland fuels and human patterns of interaction with the wildland.

It is generally accepted that, as income increases, individuals are less likely to partake in careless behavior, such as criminal behavior. In our model, we control for activity at home using the household median income and in the workplace using the percent of employed persons. The poverty rate is used to measure the effect of income on accidental wildfire.

Out of sample prediction: Using a jackknife procedure, an out of sample prediction was made for each county for 2003 through 2005 using a leave-one-out design. The jackknife procedure estimates the model for each prediction using all of the data set except for the observation left out of the data set, which is then predicted (out-of-sample). In this way, an out-of-sample prediction of the number of accidental fires was made for each county for each year between 2003 and 2005. These predictions were then compared to the actual number of fires, producing a mean absolute error and a root mean squared error (RMSE). The accuracy of the model was then compared to a naïve model that assumed that the number of accidental wildfires for the current year would be the same as the previous year. (This naïve model was also subjected to a jackknife procedure for comparison purposes.) The prediction model has a mean absolute error of 1.89 while the naïve model is 2.39. The RMSE for the prediction model is 2.94 while the naïve model is 3.99. Thus, the model developed in this paper has better predictive power than the naïve model.

Discussion and conclusion

This paper focuses on whether 'broken window' variables, which signal the presence of neighborhood apathy and a decreased probability of receiving negative consequences, result in accidental wildfires. In order to test this theory, a model was developed of unintentional human caused wildfires as a function of constructed 'broken window' indices (among other variables expected to also partially explain accidental fire ignitions). The model shows that in addition to signaling a lower cost of crime, 'broken windows' seem to create a lower level of fire safety through decreased indirect consequences (e.g., punishment), perceived decreased direct consequences (e.g., damage caused by an uncontrolled fire), and/or increased costs to implement safety precautions (e.g., identifying safe practices) compared to non-'broken window' communities. That is, evidence of norm violating behavior (i.e., 'broken windows' or social disorder) results in increased accidental wildfires.

Both of the 'broken window' variables that we tested, vacancy rate and disorder (previous year's arrests for prostitution, vandalism, vagrancy, curfew violation, public drunkenness, drug possession and sale, and runaways), are positively correlated with human-caused unintentional wildfires at a 10 % statistically significant level, thus, confirming that 'broken window' variables correlate with accidental wildfires. The elasticity of the vacancy rate is 0.18 while the elasticity of disorder is 0.02. The elasticities of accidental wildfires are similar to that of wildland and non-wildland arson found in previous research (see Thomas et al. 2010). As seen in Table 6, the elasticity of the vacancy rate ranges from 0.18 to 0.97 for the three types of fire: wildland arson, non-wildland arson, and accidental wildfire. Disorder has varying effects on the different types of arson; however, it is positively correlated with non-wildland arson and accidental wildfires.

Police normalized by population has an effect that is similar (but opposite in sign) to that of vacancies, assuming all other regressors remain the same.

This analysis reveals that proxies for social disorder (i.e., 'broken windows' or visible evidence of norm violating behavior) can be used to identify areas that are prone to human caused unintentional wildfires. These results suggest that social collaboration and crime prevention programs as well as wildfire safety programs may be effective tools in reducing rates of accidental wildfire ignitions and associated damages by reducing an individual's cost of implementing safe practices and increasing the costs, both real and perceived, of careless behavior. Accident-prone areas are often associated with social disorder, where shared perceptions on the importance of safety and taking preventative measures are absent. Wildland urban interface communities that recognize the importance of safety and taking preventive measures are likely to have a lower rate of accidental wildfire. Since 80 % of wildfires are human caused, the potential impact of improved safety and prevention measures could be quite significant.

Table 6: Accidental Fire Elasticities Compared to Arson Elasticities

	Wildland Arson		Non-Wildland Arson		Accidental	
Variable	ey/ex		ey/ex		ey/ex	
Vacancy Rate	5.53E-01	***	9.68E-01	***	1.75E-01	***
Disorder	-6.74E-03	*	4.93E-02	***	2.16E-02	*
Police Normalized by Population	-9.38E-02	***	-1.14E-01	***	-2.05E-01	**
Vacancy normalized by Youth Population	5.64E-01	***	2.11E+00	***	8.08E-01	***
Vacancy Normalized by Population	-1.40E+00	***	-4.36E+00	***	-9.16E-01	***

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$

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