



Impact of human factors on wildfire occurrence in Mississippi, United States



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ABSTRACT

Fires have important ecological and socioeconomic effects in fire-prone regions globally. Human-caused wildfires often pose considerable safety and environmental hazards, and can result in sizeable economic losses. This study analyzed the relative importance of temporal, spatial, and socioeconomic factors on occurrence of 52,532 human-caused wildfires in Mississippi that burned during 1991–2005. The probability of human-caused wildfires was modeled using a multinomial logit regression for unordered nominal outcomes. Results indicated that in comparison to incendiary wildfires, other types of human-caused wildfires were most likely to occur in summer. Wildfires caused by equipment use, children, and debris burning were more likely than incendiary wildfires to occur in close proximity to primary roads and railroad tracks, whereas close proximity to population centers increased the relative likelihood of wildfires caused by debris burning. Socioeconomic characteristics also influenced occurrence of many human-caused wildfires. Wildfires caused by children and debris burning were more likely than incendiary wildfires to occur in densely populated areas, whereas wildfires caused by debris burning, equipment use, and related to smoking were more likely in areas with high unemployment rates and large proportions of people below the poverty level. Wildfires related to smoking were also more likely than incendiary wildfires to occur in areas with higher median income. These findings will be helpful in predicting wildfire occurrence as well as developing new wildfire awareness and prevention strategies, allocating resources, and reducing wildfire damage costs in Mississippi and other fire-prone regions.

1. Introduction

High incidence of human-caused wildfires is prevalent in many parts of the World (Iliadis et al., 2002, Moreira et al., 2001, Riera and Mogas, 2004, Romero-Calcerrada et al., 2010, Vilar et al., 2010). Human-caused wildfires are also common in the fire-prone southeastern United States. The U.S. National Interagency Fire Center's statistics indicate that 66% of all human-caused wildfires were ignited in the southern and eastern United States (NIFC, 2016). In particular, high rates of human-caused wildfires have been observed in Alabama, Louisiana, and Mississippi (Clark, 1984, Kuhlken, 1999).

In Mississippi, where about 94% of wildfires are human-caused (Grala and Cooke, 2010), determination of the relationships between human-caused wildfire ignitions and human factors is particularly important. The number of human-caused wildfires has not substantially decreased since the 1960s, and while forestry in Mississippi is a US\$10

billion industry (Dahal et al., 2013), Mississippi forests are burned by about 4000 wildfires annually (Cooke et al., 2007, Grala and Cooke, 2010). After the landfall of Hurricane Katrina in 2005, the southern part of Mississippi experienced considerable expansion of the wildland-urban interface (WUI) due to northward population resettlement patterns (Grala and Cooke, 2010). In addition to the major state-wide WUI expansion during 1990–2000 (Zhang et al., 2008), this hurricane-triggered WUI expansion considerably raised the number of communities in the state affected by a threat of large wildfires due to increased risk of ignitions caused by people (Poudyal et al., 2012). It is expected that these areas will experience a greater number of human-caused wildfires in the future (Dickson et al., 2006). There are cases from other states validating this concern. For example, research from Florida suggests that densely populated WUI areas, where prescribed burning is rare and forests are less intensively managed, experience a relatively large number of wildfire ignitions (Mercer and Prestemon, 2005).

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Prevention and detection of these wildfires results in a substantial expense, which can limit resources available for other forest management programs.

There are many socioeconomic and sociocultural aspects contributing to frequent occurrence of human-caused wildfires in the southeastern United States (Bertrand and Baird, 1975, Putz, 2003). These socioeconomic and sociocultural aspects are blended with a long regional tradition of using fire as an essential land management tool practiced for generations and credited with multiple benefits such as eradication of pests (Shea, 1940). However, to prevent harmful effects of annual burning and protect regenerating forests federally mandated widespread fire suppression programs were implemented (Andreu and Hermansen-Báez, 2008, Dombek et al., 2004). Even though this policy was highly disputed in the southeastern United States (Pyne, 1982, Stephens and Ruth, 2005), where the use of fire was culturally accepted (Komarek, 1962, Shea, 1940), numerous counties in Mississippi adopted county-wide forest fire protection programs as early as 1931, some of which were present until 1960s (Cole and Kaufman, 1966). Ironically, as occurred elsewhere, this strategy created a significant increase in fuel loads associated with increased intensity and area of large wildfires, which are especially hazardous in the southeastern United States where fuel accumulates rapidly (Wade and Lunsford, 1989). Fortunately, understanding of wildfire risks and benefits has radically changed since the 1930s. Although it might not be applicable to all regions in the United States and all ecosystem types, contemporary fire management in the region utilizes prescribed fire as an important management tool for maintaining forest health, promoting plant and animal species biodiversity, and reducing fuel loads (Ryan et al., 2013, Wade and Lunsford, 1989).

There is a large volume of literature on factors related to wildfire occurrence. The majority of research, however, has tended to focus on biophysical factors, such as topography, climate, and vegetation (e.g., Romero-Calcerrada et al., 2010). An increasing number of studies in the United States, Europe, and other part of the World have examined relationships between wildfire ignitions and human factors (Calef et al., 2008, Collins et al., 2015, Romero-Calcerrada et al., 2010, Sturtevant and Cleland, 2007, Syphard et al., 2008, Vilar et al., 2010, Zhai et al., 2003). In the southeastern United States, previous research focusing on human factors in wildfires has been inconclusive. For example, Zhai et al. (2003) who examined, among other factors, the impact of population density, household income and education level on wildfires failed to find statistically significant correlations. Other studies, however, found relationships between wildfires and socioeconomic factors. For example, in Florida, county-level population and poverty were positively related to the number of annual wildfires, whereas unemployment rate was negatively related to ignitions and burned area (Mercer and Prestemon, 2005). Others have found that wildfires tend to occur more often within close proximity of transportation networks and urbanized areas (Grala and Cooke, 2010, Maingi and Henry, 2007, Zhai et al., 2003). Pezzatti et al. (2013) and Syphard et al. (2008), based on research conducted in Switzerland and the United States, indicated that although biophysical factors, such as fuel accumulation and flammability, play a major role in fire hazard reduction, human factors should also be included in these efforts because people increase the number of wildfire ignitions, change their spatial distribution, and affect fire regimes. Similarly, Mavsar et al. (2013), based on the review of decision support systems utilized for fire management in North and South Americas and Europe, emphasized the importance of incorporating economic factors, in addition to biophysical and weather factors, when evaluating effectiveness of wildfire management investments. A holistic approach that includes socioeconomic factors coupled with biophysical factors will help better understand wildfire ignitions and facilitate development of more effective wildfire prevention strategies.

Past studies examining occurrence of wildfires focused on incendiary wildfires or wildfires in general, without distinguishing among types of human-caused ignitions or investigating their relationships to

human factors (Calef et al., 2008, Sturtevant and Cleland, 2007, Zhai et al., 2003). Some researchers grouped wildfires in two simple categories to distinguish between human-caused and lightning-caused wildfires (Stephens, 2005). Others focused specifically on occurrence of arson wildfires with respect to the economic and social factors as well as the importance of law enforcement efforts (Prestemon and Butry, 2005, 2008, Prestemon and Donovan, 2008). To distinguish them from deliberately set fires, wildfires with accidental ignition causes (such as debris burning, campfire escapes, smoking, children, and equipment use) were often grouped and examined separately from other wildfire categories (Prestemon et al., 2010). Human-caused wildfires of different ignition origins, however, respond differently to various human factors and might result in different area burned (Syphard and Keeley, 2015, Yang et al., 2007). Thus, different types of human-caused wildfires might require different approaches in their prevention and suppression (Martinez et al., 2009). For example, Abt et al. (2015) demonstrated that different wildfire prevention activities differed in their effectiveness to lower occurrence of specific human-caused ignitions. Similarly, Prestemon et al. (2010) determined that different wildfire prevention activities had different efficacy in reducing wildfire damages of examined ignition causes and suggested customizing prevention activities to specific wildfire causes to increase prevention benefits. More recent studies, conducted by Abt et al. (2015) and Syphard and Keeley (2015), which incorporated different individual human causes of wildfires, also confirmed the finding that some prevention programs were effective for some wildfire types but not for other wildfire types. Determining the importance of human factors in influencing occurrence of wildfires is particularly important in the southeastern United States, where human-caused ignitions coincide with flammable fuels.

This study aimed to better understand the relationships between selected temporal, spatial, and socioeconomic factors, and occurrence of wildfires in Mississippi. The primary objective was to determine how these factors affected relative occurrence probability of different wildfire types with human-caused ignition origins. The study focused exclusively on human-caused wildfires with accidental as well as deliberate ignition causes and made distinctions between individual wildfire types. A better understanding of how spatial, temporal, and socioeconomic factors affect occurrence of human-caused wildfires will be beneficial to fire and resource managers, and decision-makers in developing more efficient wildfire management plans, implementing successful awareness and prevention programs, and developing more effective wildfire policies. The results will be helpful in managing human-caused wildfires not only in the southeastern United States but also in other fire-prone regions where human-caused wildfires are common.

2. Materials and methods

2.1. Study area

Mississippi is a rural state located in the southeastern United States (Fig. 1). Forests cover 7.9 million hectares (ha), which corresponds to approximately 63% of state total land area (Oswalt, 2015). Almost all forest land in Mississippi (99%) is classified as timberland and the most common forest types include loblolly-shortleaf pine (39%), oak-hickory (25%), oak-gum-cypress (13%), and oak-pine (10%) (Oswalt, 2015).

Mississippi has had historically one of the largest numbers of human-caused wildfires in the United States (Cole and Kaufman, 1966, Kuhlken, 1999). Forest fire occurrence rates during 1966–1973 indicated that the rate of fire occurrence in 23 of the 82 Mississippi counties was classified as very high and in additional 14 counties as high (Bertrand and Baird, 1975). The concentration of high occurrence rates consisted of a block of the 18 southernmost counties and a few smaller clusters in central and northeastern parts of the state. The agricultural Mississippi Delta region and western counties had the

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