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Wildland fire risk and social vulnerability in the Southeastern United States: An exploratory spatial data analysis approach

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ABSTRACT

The southeastern U.S. is one of the more wildland fire prone areas of the country and also contains some of the poorest or most socially vulnerable rural communities. Our project addresses wildland fire risk in this part of the U.S and its intersection with social vulnerability. We examine spatial association between high wildland fire prone areas which also rank high in social vulnerability ("hot spots") for Alabama, Arkansas, Florida, Georgia, Mississippi, and South Carolina. We also look at the proximity of hot spots to wildland fire mitigation programs. We hypothesize that hot spots are less likely than high wildland fire risk/low social vulnerability communities to engage with mitigation programs (e.g., Community Wildfire Protection Plans or Firewise Communities). To assess our hypothesis, we examined mean distances between: 1) hot spots and mitigation programs and 2) high wildland fire risk/low social vulnerability communities and mitigation programs. Overall, results show longer mean distances from hot spots to mitigation programs, compared to distances for high wildland fire risk/low social vulnerability communities. This finding provides support for our hypothesis and suggests that poorer communities in the southeast with high wildland fire risk may be at a greater disadvantage than more affluent, high fire risk communities in these states.

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1. Introduction

This investigation examines the association between wildland fire risk and social vulnerability in six states in the southeastern U.S.—Alabama, Arkansas, Florida, Georgia, Mississippi, and South Carolina. Recent studies conducted outside the South suggest that poorer communities such as those prevalent in the southern Black Belt[2] and elsewhere across the rural South would face greater wildland fire risks than middle-class or affluent communities (Ojerio, 2008; Ojerio et al., 2008; McCaffrey, 2004; Lynn and Gerlitz, 2006; Center for Watershed and Community Health, 2001). Social vulnerability, in terms of low socio-economic status of residents, has the effect of exacerbating community risk to wildland fire occurrence and devastation because socially vulnerable populations are generally less able to either mitigate wildland fire risk or recover from such events (Cutter et al., 2000; Lynn and Gerlitz, 2006; Evans et al., 2007; Blaikie et al., 1994, p.3). For instance, Mercer and Prestemon (2005) found a positive association between poverty and area of wildland burned and wildland fire intensity, suggesting that once wildland fires are ignited, poorer communities have fewer resources to extinguish fire.

We use Exploratory Spatial Data Analyses (ESDA) to look at possible links between wildland fire risk and social position. Our objective is to identify descriptive clusters of wildland fire risk and social vulnerability—"hot spots," defined as areas with both above average fire risk and social vulnerability; or "cold spots," geographies with low wildland fire risk and social vulnerability. Further, we examine the proximity of wildland fire mitigation programs to hot spots and other clusters to assess whether communities facing the greatest risks, in terms of both biophysical and socio-demographic characteristics, have the requisite community-based programs to lessen the effects of wildland fire devastation.

1.1. Wildland urban interface and non-wildland urban interface settlements in the South

A study of southern poverty commissioned by former U.S. Senator Zell Miller of Georgia found that in 2000, 13.6 million poor people

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[2] The Black Belt is comprised of 623 counties contained in eleven states of the former Confederacy—Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia. The region holds 18% of the nation's population (Allen-Smith et al., 2000). These counties are mostly adjacent although they span several states (Wimberley and Morris, 1997).

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lived in the South, representing 40% of total U.S. poverty (Carl Vinson Institute of Government, 2002). Along with high poverty concentrations, however, the South also contains areas of affluence in urban metropolises such as Atlanta, Georgia and wealth pockets in amenity-rich wildland areas. The South contained six of the fastest growing counties in the nation, in terms of percentage change in population from 1 April 2000 to 1 July 2009 (U.S. Census Bureau, 2009a).

Population growth increases demand for housing and other development, much of which contributes to the expanding Wildland Urban Interface or the WUI—"the area where structures and other human development meet or intermingle with undeveloped wildland" (http://silvis.forest.wisc.edu/projects/WUI_Main.asp). WUI growth in turn, increases the likelihood of wildland fire ignition caused by humans, given the closer proximity of human dwellings and activities to woodlands (Macie and Hermansen, 2002). Research indicates that WUI expansion is driven largely by affluent migration to peri-urban areas (Rodrigue, 1993; Collins, 2008a,b). In many instances then, WUI settlement implies higher income strata populating woodland and wildland areas.[3]

Federal mandates for wildland fire mitigation efforts prioritize WUI communities (Lynn and Gerlitz, 2006; Western Governor's Association, 2002). This is justifiable given the combination of physical and social factors (increasing population and housing density) contributing to higher wildland fire risk in the WUI. However, less densely populated rural areas outside the WUI containing abundant vegetation may be at a comparable risk of wildland fire.

Importantly, non-WUI settlements have been found to contain higher percentages of lower income populations, in contrast to the WUI. In Oregon and Washington, Lynn and Gerlitz (2006) found a higher percentage of poor people in a class of wildlands they term Inhabited Wildlands, as compared with the WUI. As well, analysis of county-level WUI data[4] for the six states included in this study shows that non-WUI acreage in nonmetropolitan counties[5] varies positively with percentage of population below the poverty threshold ($r = 0.363$; $p < 0.0001$; correlation between a county's WUI acreage and percentage of population below poverty is $r = -0.439$, $p < 0.0001$) (Radeloff et al., 2005). Hence, those places where development is expanding into rural wildlands are less likely to be in high poverty counties in Alabama, Arkansas, Florida, Georgia, Mississippi, and South Carolina.

Again, however, our interest in wildland fire across these southeastern states concentrates on those socially vulnerable populations that locate in nonmetropolitan areas outside the WUI. Thus, our analysis includes not just the WUI but also less densely settled, high vegetation places outside the WUI that contain long-established, socially vulnerable groups. These populations are prevalent in Black Belt counties such as Jefferson County, Mississippi and Perry County Alabama, where 37.5 and 31.7%, respectively, of the population is classified as impoverished (U.S. Census Bureau, 2009b).

2. Wildland fire risk in the South

Physiographic features contribute significantly to wildland fire risk in the South (Stanturf et al., 2002; Monroe, 2002). Critical factors are long growing seasons with frequent rainfall and wind, which contribute to abundant vegetation. This growth, along with a high frequency of lightning strikes and lack of a persistent snow layer, increase the likelihood of wildland fire.

The greatest number of wildland fires, by region, occurs in the South (National Interagency Fire Center, Wildland Fire Statistics, n.d.). In 2007, one-half of all reported wildland fires in the nation occurred in the thirteen states comprising the U.S. Forest Service's Southern Region; in 2006, more than one-half of all reported wildland fires in the nation were in the South, and 42% of all large wildland fires reported were in this region (Andreu and Hermansen-Báez, 2008).

In pre-industrial times, Native Americans and early European settlers used fire to reduce fuel loads. The advent of agricultural and industrial development during the nineteenth century resulted in wide-spread loss of forest cover throughout the South. To aid forest regeneration in the early twentieth century, fire suppression programs were implemented across the region. However, decades of fire suppression have resulted in substantial fuel buildup in Southern woodlands, which contribute to an increased likelihood of wildland fire (Fowler and Konopik, 2007; Monroe, 2002).

In addition, severe drought conditions over the past several years have made some areas in the region especially susceptible to wildland fire. In Florida, for instance, state fire officials reported 1847 wildland fires on state and private lands from January to April 2009. This number represents an increase of 88% over 2008 figures for the same period (Florida Division of Forestry, 2009).

The Southern Group of State Foresters', 2005 report, *Fire in the South*, identifies a number of factors contributing to the problem of wildland fire in the region. These include the fact that there is relatively little federally owned land in the South, which makes states responsible for wildland fire protection on greater than 94% of the region's land area. Again, the wildland urban interface (WUI) exacerbates wildland fire threat in many areas; and local fire departments must contribute heavily to fire suppression. Also, changing demographics in heavily forested areas makes the task of prescribed burning harder to implement, resulting in increased fuel loadings in some communities.

3. Social vulnerability and wildland fire risk

Haque and Etkin (2007) write that an after-the-fact response to disaster emphasizing cleanup and recovery efforts has for the most part been replaced with a "vulnerability/resilience paradigm." This perspective places as much emphasis on the social dimensions of disaster, that is, on suspected societal conditions and inequities which may cause some groups to be less prepared for and less able to recover from hazard events, as physical causes.

In a review of the literature on poverty and disasters in the U.S., Fothergill and Peek (2004) describe disasters as a "social phenomenon" and cite a number of studies showing that poorer people are more likely than other income groups to perceive greater risks from natural disasters but are less likely to respond to disaster warnings. Poor people also suffer disproportionately from the physical and psychological impacts of disasters, experience higher mortality rates, and find it more difficult to recover after disasters. The authors conclude that these findings "…illustrate a systematic pattern of stratification within the United States" and that disasters often highlight a priori disparities in social well-being (Fothergill and Peek, 2004, p. 103).

Cannon (in Haque and Etkin, 1994) makes explicit social variables that contribute to social vulnerability—social, economic, and political factors. These factors can either enhance or detract from a community's ability to mitigate disaster. Along similar lines, Cutter et al. (2000) argue that socially vulnerable groups such as the elderly, lower income, racial minorities, and women are more likely to be exposed to a larger number of hazards and or be less able to recover from disasters (e.g., chemical spills, hurricanes, wildfire), than wealthier, more able-bodied individuals and communities. Morrow (1999) and Lynn and Gerlitz (2006) also posit that poor communities are less able to absorb the effects of natural disasters.

[3] Collins (2005) stresses that poor communities may coexist with affluent populations in the WUI.

[4] Data source: Forest and Wildlife Ecology, University of Wisconsin at Madison. Wildland Interface Maps, Statistics, and GIS Download (http://silvis.forest.wisc.edu/projects/WUI_Main.asp.

[5] As measured by the USDA's Rural–Urban Continuum Codes (http://www.ers.usda.gov/briefing/Rurality/RuralUrbCon/).

Similar to Cutter et al. (2000), Ojerio (2008) examined both biophysical and social data to assess the vulnerability of census block groups in Arizona to wildland fire risks. Results consistently showed that census block groups comprised largely of poor non-Whites (Navajo and Apache) were less likely than majority white census block groups to participate in either state-sponsored grants aimed at wildland fire mitigation, community wildfire protection programs, or the Firewise Community program.

Importantly, Collins (2008a) critiques assumptions of risk exposure in the First World which assume that higher income households willingly expose themselves to risk by locating in aesthetically pleasing, yet ecologically fragile environments. Marginalized groups, he argues, are rendered invisible in these settings. Collins (2008a) offers instead a political ecology view of risk exposure in developed nations which makes marginalization relative. He stresses that socially vulnerable populations exist alongside the well-heeled in places with high environmental risk in developed nations. However, state and market institutions (local fire protection and fire risk insurance) act to insulate the rich from devastating loss in the event of disaster by the provision of such services. Marginal communities, conversely, absorb the risk avoided by the wealthy because of their relative inability to access these safeguards.

Collins' (2008a) focus is the contribution of institutions to the facilitation of more affluent communities. A more comprehensive look at the advantages accruing to the rich (or disadvantages of the poor) necessitates an examination of agency; that is, not just the larger society shielding some sectors from harm, but also the activities initiated by the well-off to insulate their properties from wildfire loss. Not only do the more affluent have better access to structural services to mitigate fire, but residents act at the individual and community level to prevent loss by engaging with mitigation programs in the communities where they live. Such participation distinguishes upper income areas from poor and working class communities.

4. Research hypothesis

We expect that the type of association between social vulnerability and wildland fire risk will vary geographically (cluster), with hot spot clusters (high social vulnerability/high wildland fire risk) prevalent in less densely populated, rural areas. We do not suppose that a particular type of association, for instance, “hot spots” or “cold spots” would characterize an entire state because, again, socially vulnerable populations also locate in urban areas with very low wildland fire risk; and more affluent populations concentrate in or near high wildland fire risk rural areas. However, we expect fewer wildland fire mitigation programs to exist near hot spot clusters, compared to low social vulnerability/high wildland fire risk clusters.

H1. Communities with high wildland fire risk and high social vulnerability (hot spots) are less likely than communities with high wildland fire risk and low social vulnerability to be engaged with wildland fire mitigation programs.

5. Methods

To examine the association between wildland fire risk and social vulnerability in the six-state region, we first identified indicators of wildland fire risk and social vulnerability at the Census Block Group (CBG) level. We chose the CBG as the unit of analysis because this geography approximates community groupings. The U.S. Census Bureau defines a CBG as an aggregation of blocks, with blocks being analogous to city blocks demarcated by streets; in rural areas CBGs can contain an extensive number of square miles and do not have street boundaries. Also, the CBG level approximates the spatiality at which most wildfires occur; and for the variables included in our analyses, the CBG provides the most detailed spatial resolution publicly available.

5.1. Wildland fire susceptibility index

We selected the Wildland Fire Susceptibility Index (WFSI) as our indicator of wildland fire risk. The index is one of several indices produced by the Southern Wildfire Risk Assessment (SWRA). The SWRA is the first comprehensive wildland fire risk assessment of its kind in the nation. It is supported by the thirteen state forestry agencies that comprise the USDA Forest Service's Southern Region, in partnership with the USDA Forest Service, USDI Fish and Wildlife Service, USDI National Park Service, Bureau of Indian Affairs, and the Department of Defense. The WFSI measures on a scale of zero to one the probability[6] of an acre burning, based on surface fuels and forest conditions, weather, historical fire sizes, and historical suppression effectiveness (Buckley et al., 2006a,b).

The index includes three key components: 1) probability of fire occurrence, 2) fire behavior, and 3) fire suppression effectiveness. The first component, probability of fire occurrence, is comprised principally of Fire Occurrence Areas (FOA) and Weather Influence Zones (WIZ) (Buckley et al., 2006a, p.41–52). FOAs are determined by historical data pinpointing fire ignition. Quantitatively, FOA is the historical mean of ignitions calculated as the number of fires per year per thousand acres. Periods of fire occurrence were not specified but rather referred to generally as “fire history reports,” which we assume were supplied by state and federal land management agencies. Fire ignition data were collected between 1997 and 2002.

Weather also influences probability of fire occurrence. To incorporate this variable, WIZs or weather zones were designated for the thirteen southern states, and daily weather observations for each WIZ were recorded from 1 January 1994 to 31 December 2003 (Buckley et al., 2006a). Weather conditions were categorized into percentiles that indicated conditions which were more or less conducive to fire ignition—low, moderate, high, and extremely high percentiles. Various land management agencies and the National Oceanic and Atmospheric Administration supplied weather data.

The second significant component of WFSI is Fire Behavior (rate of spread [ROS], crown fire potential, and flame length). ROS is simulated using FB3 DLL Windows software (commercial software licensed by Fire Program Solutions LLC). Fire Behavior attributes, in turn are calculated based on surface fuels, canopy closure, canopy characteristics,[7] and topography (aspect, slope, elevation). Surface and canopy fuels data were obtained from crosswalks of existing datasets. Fire behavior is estimated in 30×30 m cells with specific weather conditions. ROS is calculated for the four weather categories—low, moderate, high, and extreme.

Lastly, WFSI includes Fire Suppression Effectiveness which is a function of Final Fire Size (FFS) and ROS. Fire suppression effectiveness is the comparison of actual fire sizes to a theoretical size which assumes fire spreads under stable conditions with homogenous weather and fuel conditions with no suppression activity. Data used for these calculations are from states and federal agencies for the time period 1997–2002. The final WFSI figure for a 30×30 m cell in a given WIZ is the summation of the respective WFSI calculations for the four weather percentile areas. WFSI is available in a raster format.

To facilitate analysis at the CBG level, basic statistics (maximum, mean, minimum, and standard deviation) were calculated for all 30 m pixels within each CBG using the “summarize zones” function in the ESRI's (Environmental Systems Research Institute) Spatial Analyst

[6] Although due to some necessary assumptions such as fuel homogeneity, it is not the true probability.

[7] Data on canopy characteristics were limited by the lack of extant data and funding to collect primary canopy fuels data, canopy ceiling height, canopy base height, and canopy bulk density (Buckley et al., 2006a, p. 49).

extension for ArcVIEW. Values ranged from 0 to 0.86, mean 0.04 (standard deviation 0.086), and median 0.005.

5.2. Social vulnerability index

Concurrently, we constructed an index to measure social vulnerability (SOVUL). We define vulnerability as marginalization, characterized by the lack of ability to assertively navigate social systems or to move progressively towards higher living standards in terms of material wealth and influence. As indicated, a number of researchers have found a range of social indicators associated with an individual, household, or community's ability to mitigate and/or recover from disasters. Cutter et al. (2000) identified eleven county-level factors that influence social vulnerability. These have to do with personal wealth, housing stock and tenancy (percent mobile homes in county), and race/ethnicity. Morrow (1999) includes similar factors—physically and mentally disabled, elderly, female-headed households, and the homeless. Cutter et al. (2003) developed a Social Vulnerability Index (SoVi[8]) which examines how socio-demographic characteristics influence climate related hazards—drought, floods, hurricane force winds, and sea-level rise—in the southeast (Oxfam, 2009). Wildland fire hazard is not included among the environmental risks this group examines.

Our SOVUL index includes percent of population below poverty, percent of population 25 or older without a high school diploma, percent African American, percent of housing structures that are mobile homes, and percent of renter occupied housing units. Each of these variables can have a direct bearing on social vulnerability for both individuals and communities. As discussed, persons or households below poverty and those with lower education levels typically have less efficacy in obtaining services or information about environmental protection. Also, race often figures into issues involving services and information access. White, middle-class neighborhoods and communities typically have a greater number of facilities and services compared to poorer, minority areas (Taylor et al., 2007; Taylor, 2000; Wolch et al., 2002).

Racial status tends to correlate positively with other socio-demographic and economic indicators such as those included in our index—particularly poverty and education. However, we also believe that the descriptor "African American" or "Black" carries an additional weight beyond that of income or education. This relates to both overt and more subtle forms of discrimination from the larger society and also to self-imposed racial segregation which continues de facto racial separation. Mobile homes are less able to withstand natural disasters such as hurricanes because the building material is generally of lower quality than constructed dwellings. This may also be the case with fire resistance, as mobile structures are less likely than constructed homes to be made of fire resistant, durable materials. Finally, renters have less control over building materials, landscaping, fire insurance or other safeguards against wildland fire, which could result in greater vulnerability for this group.

Because of overlaps between race and the other variables included in SOVUL, we examined the degree of multicollinearity for the variables comprising the index by examining a regression model where WFSI was the dependent variable and percent black, percent below poverty, percent low education, percent renter and mobile home were predictors. Here, we wanted to detect inflated standard errors by looking at the variance inflation factor (VIF), as multicollinearity is indicated by fluctuating standard errors. Generally, VIF values greater than ten may indicate multicollinearity among variables. VIF values for each of our predictors were below three, which suggests low or moderate multicollinearity. Frequencies for variables comprising SOVUL were downloaded from the 2000 U.S. Census Bureau Summary File 3 sample data tables. Data were obtained for each CBG in the six-state region. We downloaded total population; total African American population; total population 25 years and older; both male and female population 25 and older with varying degrees of educational attainment; total population for whom poverty was determined; population with income below poverty; total housing units; total mobile home units; total occupied housing units; and total renter occupied housing units.

From these frequencies, percent African American, percent over 25 without high school diploma, percent below poverty, percent mobile home dweller, and percent renter were calculated. Percentages for each indicator (e.g., percent below poverty, black, etc.) were summed to produce the SOVUL value for a given census block group. Values were not standardized, and all variables are assumed to carry equal weight.

SOVUL values ranged from 0 to 3.64, with a mean of 1.10 (standard deviation 0.64) and median 1.03. Values larger than the mean indicate high social vulnerability. Zero values would be observed in the case of CBGs with no population.

6. Exploratory spatial data analysis

6.1. Bivariate clusters of wildland fire risk and social vulnerability

We use the LISA statistic, localized indicator of spatial association, to test the strength of association between WFSI and SOVUL and also to map these associations at the CBG level (Anselin, 1995). The correlation statistic indicates how observations of a variable in a given CBG (say i) are associated with observations of a different variable in adjacent CBGs or the "neighborhood" of the ith CBG. In our case, this involves correlations between WFSI in an areal unit, i, and SOVUL in the cluster of CBGs surrounding and including the ith CBG. Neighboring CBGs or the "neighborhood" of the ith CBG was defined based on a first order contiguity weight matrix. CBGs adjacent to the ith CBG sharing a common border length or at least a vertex were considered to be in the neighborhood. The mean neighborhood value for SOVUL and WFSI includes the value for the variable in the ith CBG, as well as the values for all CBGs adjacent to it. This was achieved by manually editing the weight matrix files.

Bivariate LISA statistics were used in GeoDa™ 0.9.5-I to map four different types of spatial clusters for WFSI and SOVUL at the CBG level. For WFSI, for example, clusters include: 1) High–High, CBGs with high wildland fire risk surrounded by CBGs with high social vulnerability; 2) Low–Low, CBGs with low wildland fire risk surrounded by CBGs with low social vulnerability; 3) Low–High, CBGs with low wildland fire risk surrounded by CBGs with high social vulnerability; 4) High–Low, CBGs with high wildland fire risk surrounded by CBGs with low social vulnerability.

Again, the high and low level of a given variable is defined in reference to its mean value for the neighborhood. We defined High–High and Low–Low clusters as "hot spots" and "cold spots," respectively, where the association between two phenomena is positive. For the other clusters (Low–High and High–Low), the associations are negative and are described as spatial outliers (Anselin, 2005). LISA scores significant at $p = 0.05$ or less were used to map statistically significant clusters. Pseudo-p values were generated for LISA statistics utilizing 999 permutation criteria available in GeoDa™ 0.9.5-I (www.geodacenter.asu.edu).

The following equation (Sunderlin et al., 2008) provides the computation of bivariate LISA based on Anselin (1995).

$$I_l = z_{xi} \sum_{j=1, j \neq i}^{N} w_{ij} z_{yj} \tag{1}$$

where, I_l is the local Moran's I (LISA); x and y are two variables of interest measured for CBG i, and neighborhood j, respectively.

[8] SoVi includes eight variables which explain 75% of the variance in social vulnerability. The variables are wealth, age, race, ethnicity, rural residence, special needs populations, gender, and employment (Oxfam, 2009).

Similarly, z_x and z_y represent the standardized z-scores for variables x and y, respectively. The term w_{ij} is the weight matrix that defines the structure of the neighborhood. LISA and weight matrices were created in GeoDa™ 0.9.5-I. This analysis uses a first order queen contiguity matrix, where $w_{ij} = 1$ if the adjacent CBG j shares a common border length or common vertex with the ith CBG. If a common border is not shared, the value is zero.

6.2. Results

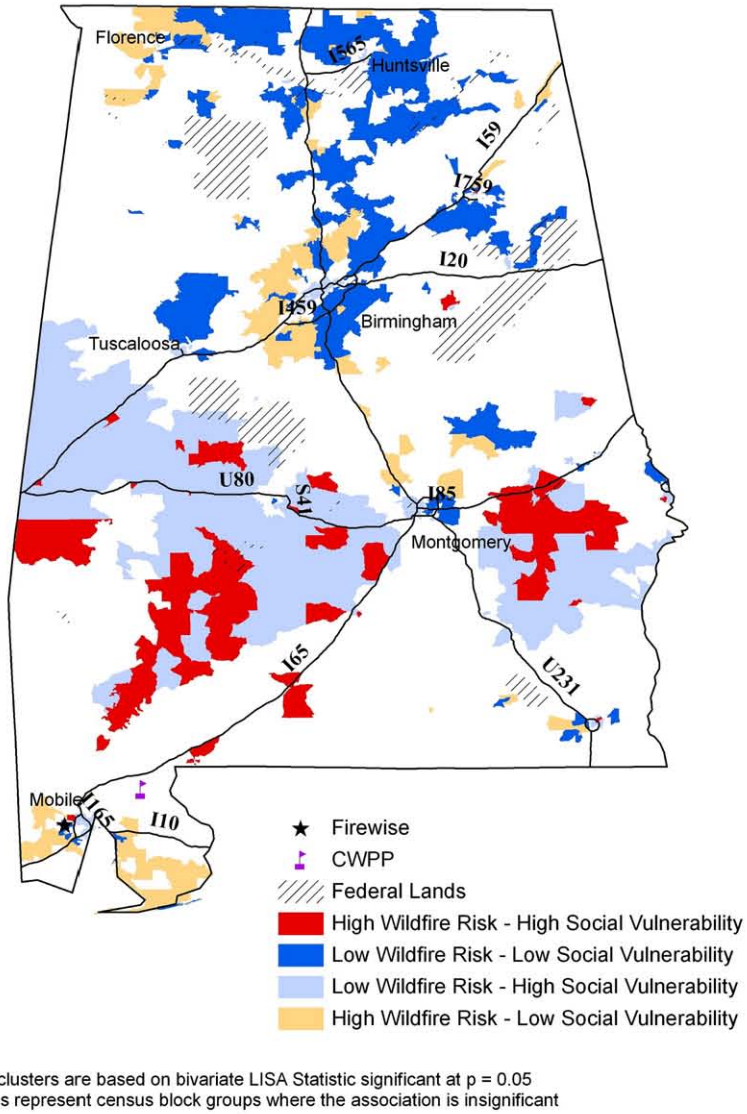
6.2.1. ESDA at the state level

Figs. 1–6 show bivariate LISA analyses for each state. In each figure, the red color indicates clusters of high wildland fire risk CBGs located in neighborhoods or clusters with high social vulnerability (High–High); dark blue clusters denote low wildland fire risk CBGs in clusters with low social vulnerability (Low–Low); low wildland fire risk/high social vulnerability clusters are shown in light blue (Low–High); and high wildland fire risk/low social vulnerability clusters are colored mango (High–Low). White areas within the study area represent CBGs where the spatial association between WFSI and SOVUL is not statistically significant.

To make the interpretation easier and more meaningful, cluster maps for each state are overlaid with interstate highway and federal land areas. Geo-visualization of clusters with such recognizable figures provides reference for illustrating the spatial location of clusters. For example, in the analysis for Alabama (Fig. 1), red clusters or hot spots are located in the southern part of the state, mostly south of Interstate-85 and US-80. Interestingly, this portion of the state contains relatively less federal land area compared to areas north of those highways. South Alabama also contains large areas of light blue clusters, which again indicated high social vulnerability CBGs in the neighborhood of low wildland fire risk CBGs.

The overall pattern of high social vulnerability (red and light blue patches) follows the spatiality of Alabama's impoverished Black Belt. The more socially vulnerable clusters are located almost exclusively in the southern part of the state. The present analyses demonstrate how low socio-economic status or socially vulnerable communities intersect with wildland fire risk. In some areas of the state's Black Belt, there is an inverse association between social well-being and this type of environmental risk (light blue); whereas in others the association is positive (red).

North Alabama stands out as a near antonym to the southern part of the state, in terms of social well-being. From Birmingham and Tuscaloosa northward, the state contains remarkably more low



Note: The clusters are based on bivariate LISA Statistic significant at p = 0.05
White areas represent census block groups where the association is insignificant

Fig. 1. Bivariate LISA based spatial clusters showing the local association between wildland fire risk and social vulnerability in Alabama.

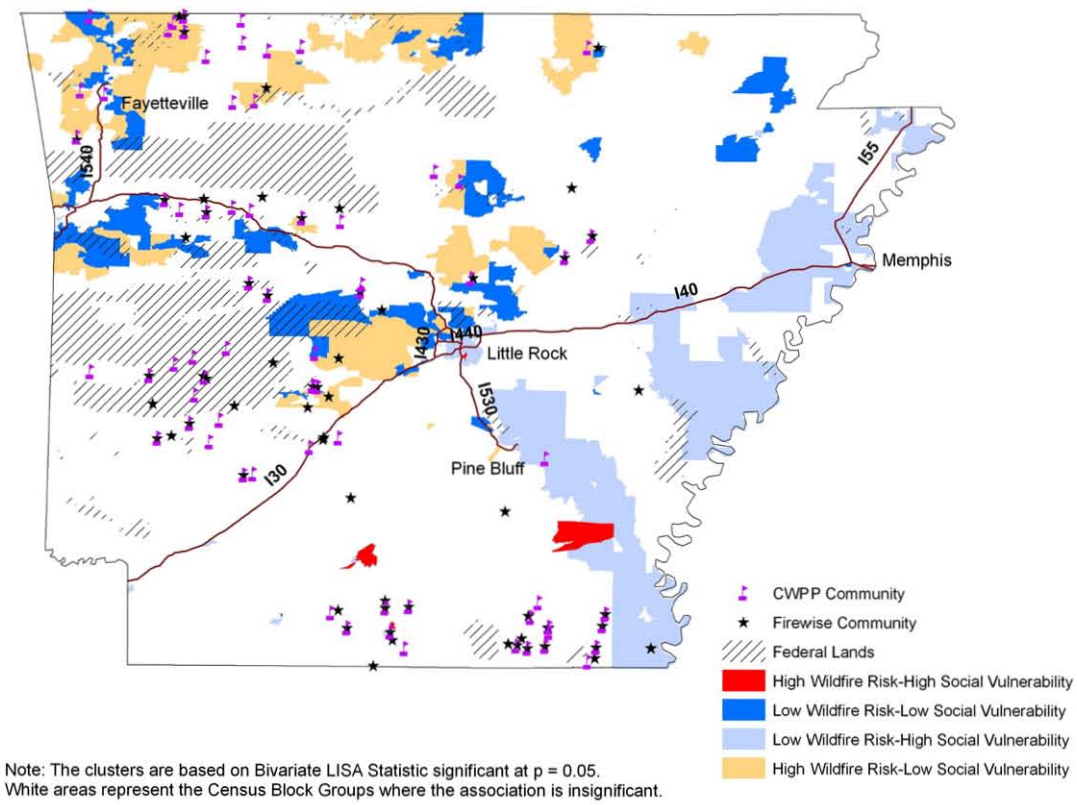


Fig. 2. Bivariate LISA based spatial clusters showing the local association between wildfire risk and social vulnerability in Arkansas.

socially vulnerable clusters. The dark blue Low–Low clusters predominate in the north; but high fire risk areas also intersect with more well-off communities in north Alabama in the Huntsville–Florence area. The only exception to this pattern is the light blue, High–Low area of central city Birmingham. The cluster here is similar to that in the rural Black Belt south of Interstate-20. This is not surprising given

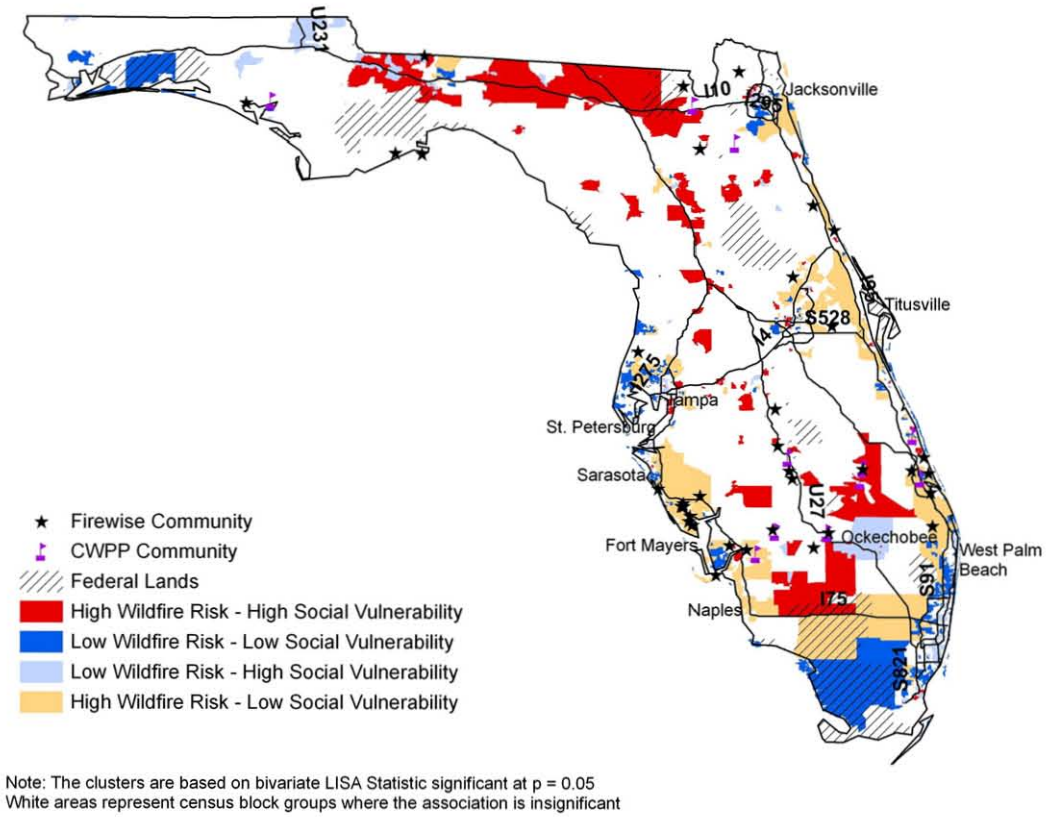


Fig. 3. Bivariate LISA based spatial clusters showing the local association between wildland fire risk and social vulnerability in Florida.

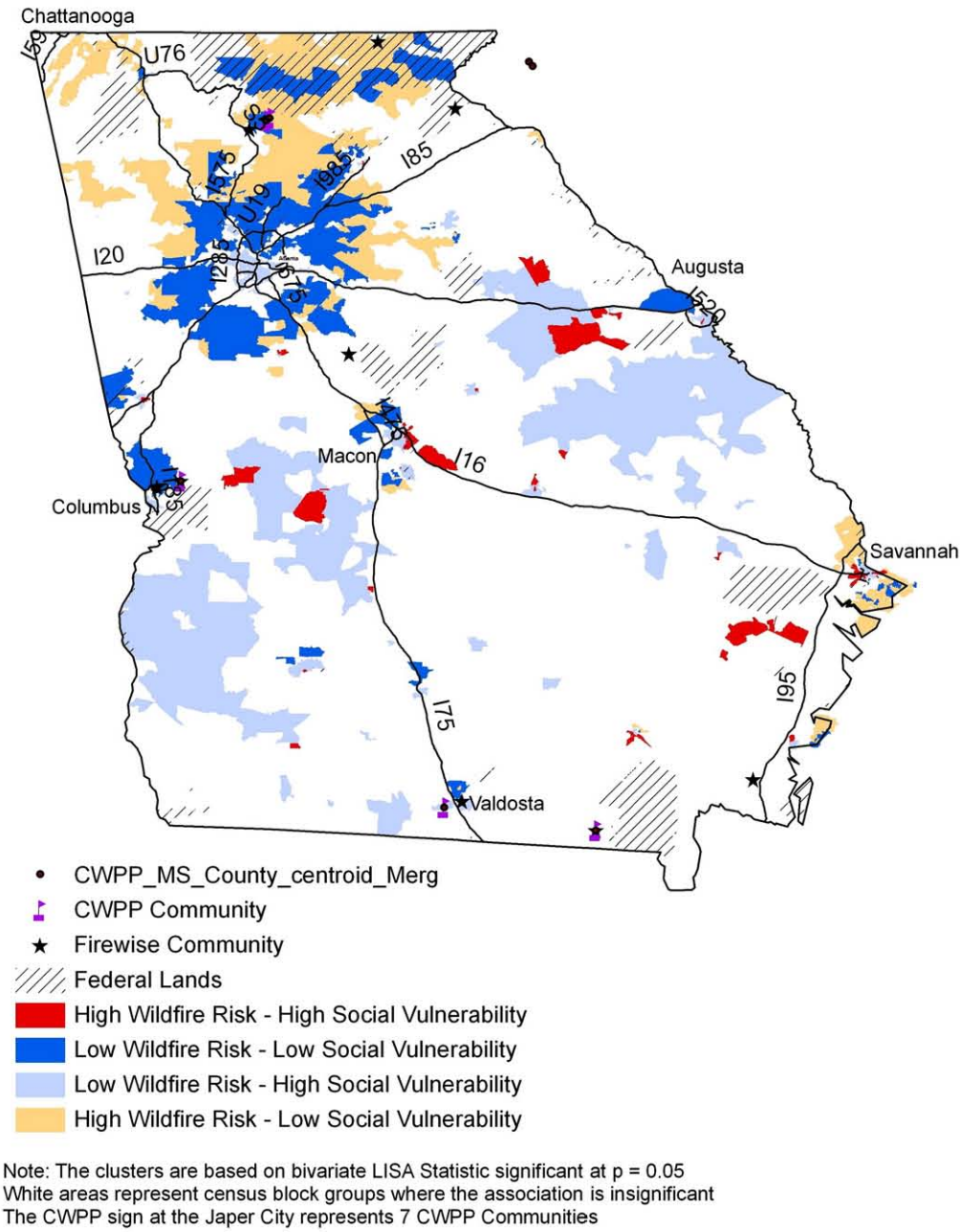


Fig. 4. Bivariate LISA based spatial clusters showing the local association between wildland fire risk and social susceptibility in Georgia.

that roughly 73% of Birmingham's city population is African American (U.S. Census Bureau, 2000). A similar phenomenon occurs around other major cities in the region.

A moderate clustering northeast of Montgomery and in the state's panhandle region is also characterized by high fire risk/low social vulnerability. Near Mobile, there is a small light blue cluster approximating the location of central city Mobile (56% African American) that is low wildland fire risk/high social vulnerability.

Fig. 2 also shows rough demarcations along socio-economic lines in Arkansas. The eastern portion of the state south of Interstate-30/40 contains more socially vulnerable CBGs; however, there are only two distinct hot spot clusters in southeast Arkansas. A light blue area is again evident near the state's capital city, Little Rock; but areas to the north and west of Little Rock are either dark blue or mango which indicate low social vulnerability. In this state, too, high wildland fire risk areas do not overlap with federal lands.

In Florida (Fig. 3), more affluent communities are located along the coast from the Jacksonville area on the Atlantic coast down to Titusville and West Palm Beach. Low socially vulnerable clusters extend inland to the Everglades on Florida's southern tip and up the Gulf coast from the Naples and Fort Myers area, along the coastline of Sarasota, up to the Tampa/St. Petersburg region. As well, higher fire risk is associated with higher income communities on both the Atlantic and south Gulf coasts and in the upper Everglades region. Hot spots are clustered in extreme north central and south central Florida. Similar to Alabama and Arkansas, social vulnerability in Georgia also varies geographically, with south Georgia containing noticeably more socially vulnerable clusters compared to suburban Atlanta area and points north. Fig. 4 shows segments of the southern Black Belt, denoted by light blue clusters and a spattering of hot spot red clusters, mainly south of Atlanta running along a line from southwest Georgia northeast to the South Carolina boarder. In contrast, dark blue clusters

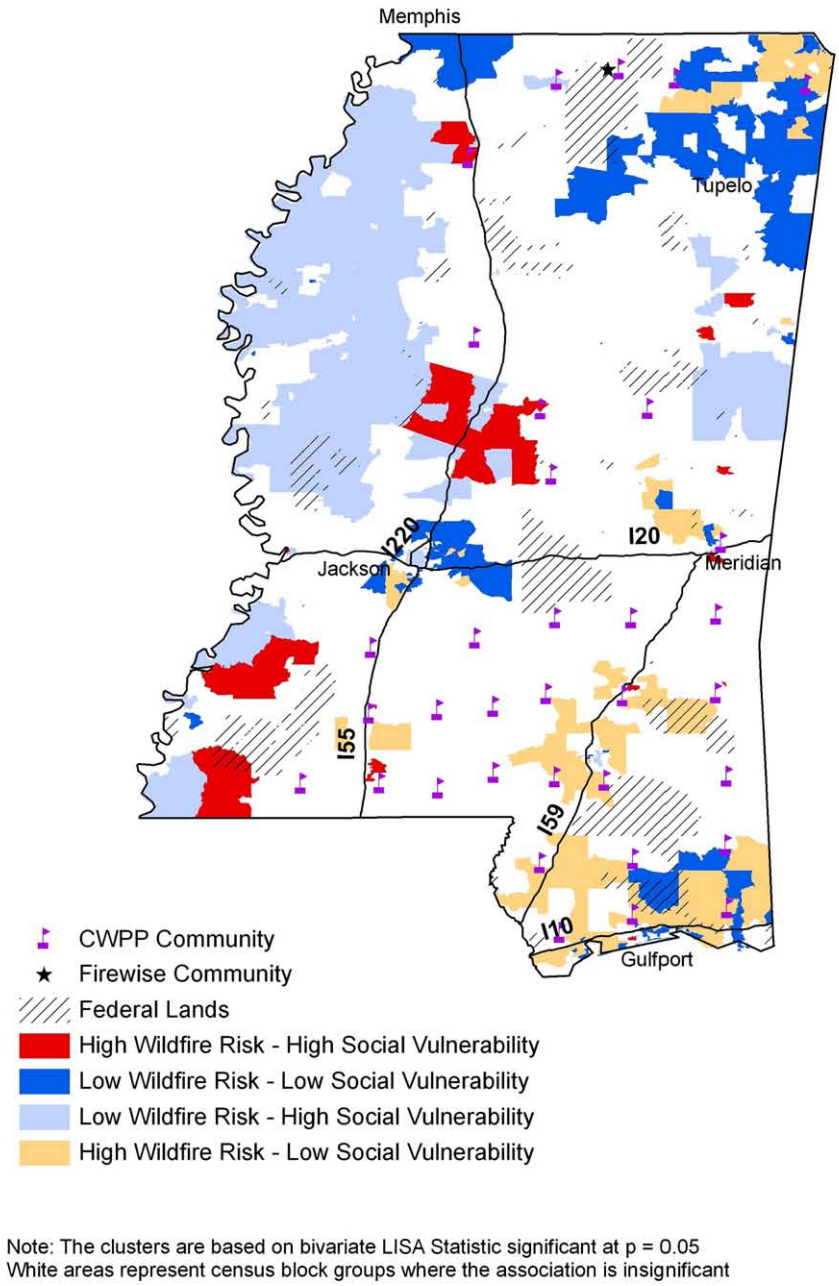


Fig. 5. Bivariate LISA based spatial clusters showing the local association between wildland fire risk and social susceptibility in Mississippi.

are located mainly in the periphery of metropolitan Atlanta and northeast Georgia around the Chattahoochee National Forest.

The Chattahoochee portion of the Chattahoochee–Oconee National Forest is located in a high fire risk area along Georgia's northern border with North Carolina; however, the Oconee preserve in the Piedmont between Interstates-20 and 16 is not. The light blue coloring distinguishes central city Atlanta from its more affluent suburbs. North of Atlanta, there are also mango colored areas which suggests higher fire risk in concert with higher socio-economic status. As well, there are smaller clusters of mango in southeast Georgia near Savannah.

Mississippi northwest of Interstate-55 contains the low lying Mississippi "Delta" or alluvial plain, which historically has been associated with high poverty rates and is indicated in Fig. 5 by light blue color. In this region, there is little overlap between social vulnerability and wildland fire risk given the higher moisture content of this terrain. Wildland fire risk is positively associated with social vulnerability in a central Mississippi cluster north of Jackson and also in southwest Mississippi; but Jackson is similar to other larger cities in terms of low fire risk and high social vulnerability. With the exception of an area to the immediate east of Interstate-55 and extreme east-central Mississippi, more areas in the western part of the state are characterized by low social vulnerability. In the north, low social vulnerability intersects more with low wildland fire risk; whereas in the south, low social vulnerability crosses with higher fire risk.

Finally, Fig. 6 shows a large portion of east South Carolina in hot spot clusters. Hot spots overlap with the Francis Marion National Forest along the Atlantic coast and also with the Sumpter National Forest on the Georgia border. There are smaller dark blue areas along the state's east coast, but these clusters are located more in the upstate region around Greenville, Spartanburg, and Columbia. A spattering of mango is also along the coast and in the extreme upstate region near Greenville.

As expected, our analyses identified socially vulnerable clusters which coincide with the rural Black Belt across the region. Again,

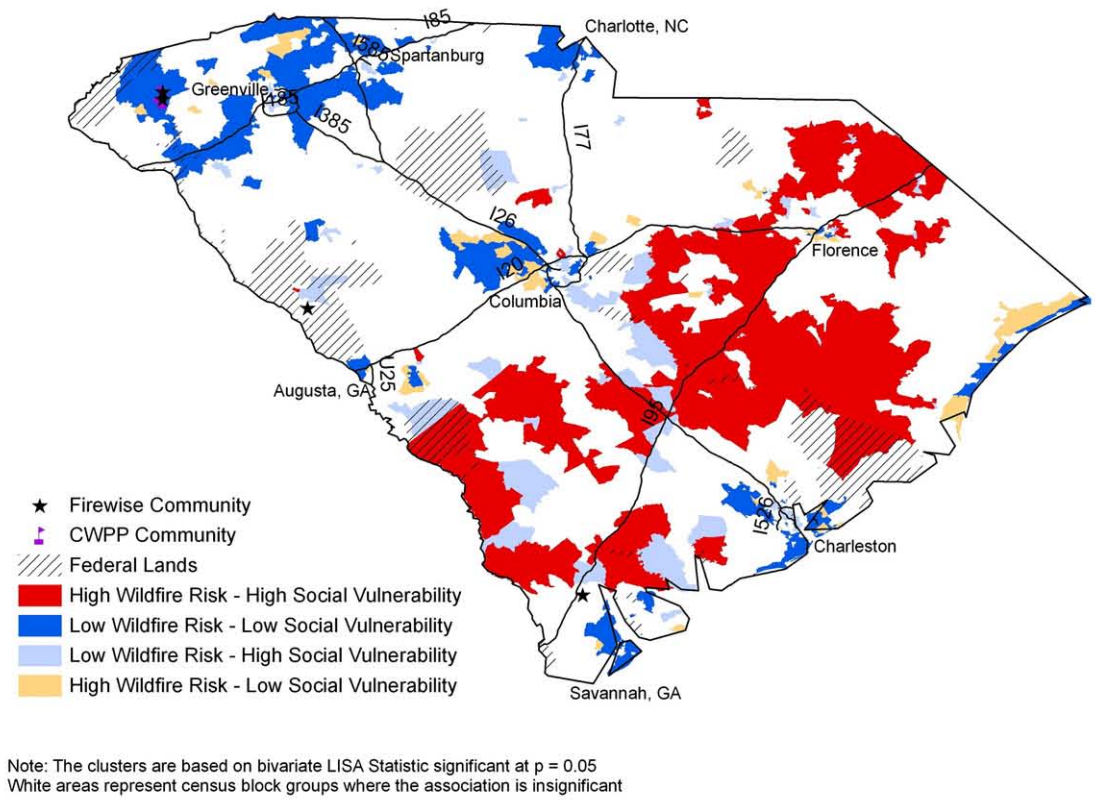


Fig. 6. Bivariate LISA based spatial clusters showing the local association between wildland fire risk and social vulnerability in South Carolina.

however, elevated wildfire risk did not overlap with social vulnerability in some areas of south Alabama, southwest Georgia, and the Georgia Piedmont. This lack of association may be explained, in part, by the three components of WFSI (i.e., weather conditions contributing to fire occurrence, fire behavior, and suppression).

Naturally occurring fires are caused by lightning. Peak lightning concentrations occur along the coast where sea breeze-forced thunderstorms are common. Higher WFSI clusters are clearly seen in the Gulf areas of Alabama and Mississippi and along Florida's coastline. The coastal plain is also characterized by a higher percentage of plant communities that burn with greater intensities on average than upland areas. In contrast to the coast and coastal plain, south Alabama, southwest Georgia, and the Georgia Piedmont are not characterized by these physical conditions.

Those areas of southwest Alabama and other states with adjacent Low–High and High–High clusters seem contradictory but may be explained by the fire suppression component of WFSI. To recount, fire suppression effectiveness is the comparison of actual fire sizes to a theoretical size which assumes the fire is spreading under steady conditions with no suppression activity. Built infrastructure such as roads and fire fighting services contribute to fire suppression efficacy. Poor road networks in some parts of west Alabama may contribute to low fire suppression scores, and hence higher WFSI scores in these CBGs. Road quality can change abruptly depending upon county resources. Poor roads, as well as mountainous landscape, are also factors that would contribute to low fire suppression effectiveness, raising the fire risk in northern Georgia. Contrast the higher fire risk for the Chattahoochee National Forest in north Georgia with the lower risk for the Oconee preserve in the Georgia Piedmont southeast of Atlanta. Most federal lands, however, have dedicated fire suppression resources, which lowers fire risk in their vicinity.

6.2.2. Spatial associations by type

Distribution of CBGs by cluster type was tabulated for each state and is presented in Table 1. In all of the states, about one-quarter of total CBGs were found to have negative associations between

Table 1
Distribution of CBGs for Alabama, Arkansas, Florida, Georgia, Mississippi, and South Carolina according to types of local spatial association between WFSI and SOVUL.

Types of association	Alabama		Arkansas		Florida		Georgia		Mississippi		South Carolina		Total	
	CBG (N)	CBG (%)	CBG (N)	CBG (%)	CBG (N)	CBG (%)	CBG (N)	CBG (%)	CBG (N)	CBG (%)	CBG (N)	CBG (%)	CBG (N)	CBG (%)
High wildland fire risk–high social vulnerability	85	2.55	6	0.28	405	4.46	58	1.21	44	2.05	248	8.68	846	3.48
Low wildland fire risk–low social vulnerability	543	16.31	268	12.95	1425	15.68	887	18.53	301	14.02	549	19.21	3973	16.36
Low wildland fire risk–high social vulnerability	589	17.69	344	16.62	1269	13.96	899	18.78	356	16.58	327	11.44	3784	15.58
High wildland fire risk–low social vulnerability	142	4.27	144	6.95	890	9.79	266	5.56	144	6.71	91	3.18	1677	6.91
Insignificant	1970	59.18	1307	63.17	5099	56.11	2678	55.93	1302	60.64	1643	57.49	13,999	57.66
Total	3329	100	2069	100	9088	100	4788	100	2147	100	2858	100	24,279	100

wildland fire risk and social vulnerability (i.e., either had high wildland fire risk and were located in higher status neighborhoods or had low wildland fire risk and located in more socially vulnerable neighborhoods). South Carolina had the highest percentage of CBGs classed as hot spots (8.68%) and Arkansas had the lowest (0.28%). South Carolina also had the highest percentage of cold spots (19.21%); and again Arkansas had the lowest cold spot percentage (12.95%). Florida had the highest percentage of High–Low clusters (9.79%) and South Carolina the lowest (3.18%).

The row totals show that roughly 3.5% of CBGs in the region were hot spots. About 16% of CBGs were in either cold spot areas or Low–High clusters; and roughly 7% were in High–Low social vulnerability areas. About 58% of the CBGs in the region exhibited no significant association between wildland fire risk and social vulnerability.

6.2.3. Distribution of wildland fire mitigation programs across the Southeast

Our primary objective is to examine the spatial relationship between: 1) hot spots and wildland fire mitigation programs and 2) High–Low areas and wildland fire mitigation programs. We would assume that those areas across the region identified as being highly susceptible to wildland fire occurrence would have a greater number of mitigation programs, compared to low fire risk communities. Our aim is to determine how such programs may be distributed in areas that are also socially vulnerable.

There are a number of federal, state, and local level mitigation programs across the country. Three key programs are Community Wildfire Protection Plans (CWPPs), Firewise Communities, and hazardous fuels reduction programs on federal lands. The latter are funded by the USDA Forest Service and USDI Department of Interior through the Healthy Forest Initiative and the National Fire Plan (NFP) (http://www.forestsandrangelands.gov/reports/documents/healthyforests/2008/healthy_forests_report_fy2008.pdf). Fuels reduction programs in the form of prescribed burns or mechanical thinning might occur on any federal lands with fuel loads sufficient to warrant reductions in loadings. Communities adjacent to those lands would accrue benefits of such treatments.

We are interested in mitigation efforts involving significantly more community initiative and input. CWPPs or Community Wildfire Protection Plans are also funded by the NFP but are founded principally by communities rather than public agencies. Communities at risk for wildland fire collaborate with public agencies, local fire departments, and municipalities to prioritize private landholdings needing hazardous fuel reduction and recommend appropriate treatments to reduce future wildland fire threats (http://hazardmitigation.calema.ca.gov/hazards/natural/fire). Typically, state forestry agencies provide information to at risk communities about CWPPs, but individual community groups or municipalities must take ownership of the plan by becoming active partners with sponsoring agencies.

Similarly, the national Firewise Communities program involves significant community input. These programs are intended to "… reach beyond the fire service by involving homeowners, community leaders, planners, developers, and others in the effort to protect people, property, and natural resources from the risk of wildland fire — before a fire starts" (http://www.firewise.org/). Because of the commitment and involvement required for successful implementation and running of both CWPPs and Firewise programs, we believe that communities with higher social and human capital (assuming high wildland fire risk) would be more likely than lower capital communities, or those communities rating high in social vulnerability, to establish these programs.

We selected CWPPs and Firewise Communities as indicators of mitigation programs on the ground. We realize there are other programs at the local and state level that could also be included, but the difficulty of obtaining data on such programs across the study area prohibits their inclusion. We obtained complete and current listings of Firewise Community locations from a national Firewise manager for each of our states. A total of 145 active Firewise Communities were reported—Alabama (1), Arkansas (91), Florida (38), Georgia (10), Mississippi (1), and South Carolina (4). It was more difficult to secure CWPP locations. The NFP website lists 730 Communities at Risk (for wildland fire) in the South covered by a CWPP in 2008 (http://www.forestsandrangelands.gov/reports/documents/healthyforests/2008/healthy_forests_report_fy2008.pdf); however, the location of these CWPPs is not mapped by NFP managers.

We contacted the individual state forestry agencies to obtain CWPP locations. For some states, CWPP data had not been assembled at the state level. In the case of Florida, for instance, individual fire districts forwarded latitudinal and longitudinal coordinates to us, and we mapped CWPP locations at the CBG. Mississippi establishes county-wide CWPPs, so the CWPPs listed for that state represent a central point in the respective counties. We obtained the most complete listing of CWPP sites for each state that was available although these listings may not be exhaustive: Alabama (1), Florida (10), Georgia (10), Mississippi (34), and South Carolina (2); but we did have a complete listing for Arkansas (109).

Despite their limitations, these mappings represent the first efforts of which we are aware that attempt to locate CWPP locations in the South. Both CWPP and Firewise programs locations are typically associated with residential or a community association address rather than a centralized address removed from communities; thus the coordinates for mitigation programs directly reflect community involvement.

To test the hypothesis that hot spots are less likely than High–Low areas to be engaged with wildland fire mitigation programs, we computed the mean distance, in kilometers, between hot spots and High–Low clusters, respectively, to the nearest CWPP location and Firewise program. Distances were computed in ArcGIS using the "simple distance" feature to determine the straight line distance from hot spot and High–Low clusters for Firewise and CWPPs, respectively. CWPP and Firewise location data were also combined into a single generic layer representing the location of both types of community mitigation programs; and the distances from hot spots and High–Low CBGs to the nearest programs were estimated.

Table 2 contains means, standard deviations, and t-tests generated from the analyses. Results show that the average distance from hotspots to CWPPs was significantly longer than from High–Low clusters to CWPPs in Arkansas, Georgia, Mississippi, and South Carolina. The distance was significantly shorter in Alabama but not significant in Florida. For Firewise, the mean distance between hot spots and these programs was longer for Florida, Georgia, and South Carolina but shorter for Alabama and Mississippi and not significant for Arkansas. For the combined programs, mean hot spot distance was longer for all states except Alabama.

It should be noted that the mean distances between a cluster type and program locations in some cases are the same or very similar. This has to do with the way hotspots and programs are spatially arranged on the ground. For instance, if most of the hotspots in a state are located close to a particular CWPP program, their mean distance to CWPPs and mean distance to CWPP and Firewise combined would be the same if there are no Firewise programs in the area. Similar observations were observed between distances to CWPP and distances to Firewise if a state had only a few programs that are located close to each other.

Of the 18 comparisons made, 12 or 66% indicated a longer average distance between hot spot clusters and High/Low clusters. Because there was only one CWPP and Firewise in Alabama, one Firewise location in Mississippi, and two CWPPs in South Carolina, these comparisons should be taken with some caution. If these comparisons and the combined category for Alabama are excluded from the analyses, eleven of the remaining thirteen means show longer distances for hot spots (84.6%). Overall, results support the research hypothesis and suggest that communities with both higher fire risk

Table 2
Mean distance of CWPP, Firewise, and combined CWPP/Firewise programs to high Wfsi/SOVUL (hotspot) and high WFSI/low SOVUL clusters in Alabama, Arkansas, Florida, Georgia, Mississippi, and South Carolina.

State	Types of association	CBG (N)	CWPP mean (km) (stand. dev.)	Firewise mean (km) (stand. dev.)	CWPP and Firewise mean (km) (stand. dev.)
Alabama	High WFSI–high SOVUL	85	173.30 (85.01)	172.40 (86.58)	172.40 (86.58)
	High WFSI–low SOVUL	142	227.19 (15.74) t = 13.50†	249.09 (168.93) t = 16.07†	227.19 (157.41) t = 14.35†
Arkansas	High WFSI–high SOVUL	6	27.42 (13.27)	25.10 (13.01)	24.75 (12.79)
	High WFSI–low SOVUL	144	18.90 (17.22) t = 2.14†	25.87 (19.87) t = −0.21	16.89 (16.53) t = 2.05†
Florida	High WFSI–high SOVUL	405	75.45 (44.13)	34.28 (23.53)	33.56 (23.83)
	High WFSI–low SOVUL	890	77.41 (45.06) t = −2.87	28.03 (22.77) t = 15.38†	26.57 (23.00) t = 16.92†
Georgia	High WFSI–high SOVUL	58	145.52 (54.52)	92.61 (37.68)	92.41 (37.69)
	High WFSI–low SOVUL	266	74.65 (46.29) t = 16.40†	55.49 (32.29) t = 12.51†	55.37 (32.37) t = 12.50†
Mississippi	High WFSI–high SOVUL	44	26.74 (19.88)	304.47 (113.72)	26.74 (19.88)
	High WFSI–low SOVUL	144	14.68 (12.43) t = 6.15†	377.01 (126.89) t = −11.04†	14.68 (12.43) t = 6.15†
South Carolina	High WFSI–high SOVUL	248	276.33 (39.26)	150.33 (64.11)	150.33 (64.11)
	High WFSI–low SOVUL	91	234.18 (106.95) t = −4.83†	124.44 (68.77) t = −8.25†	124.44 (68.78) t = −8.25
	Total	2523			

† = significant at 0.05 or less.

and higher levels of social vulnerability are less involved with these particular wildland fire mitigation programs.

7. Discussion and conclusion

Reasons why socially vulnerable communities are less engaged with Firewise Communities or CWPPs may have to do with a range of factors emanating from lack of interest to again, a dearth of social and human capital in these communities. A state forester in Florida stressed that information about CWPPs, Firewise, and other mitigation programs is readily available from the Florida Division of Forestry, but individual homeowners and communities express varying levels of interest in adopting the programs.[9] Also, unpublished data from our recent analysis of southern landowner knowledge and understanding of wildland fire mitigation programs indicated that overall, roughly 40% of landowners reported that they had done "nothing" to prevent wildfire on their rural land; and nearly 46% of African Americans said they had taken no action to mitigate wildfire although blacks were more likely than whites to say they aware of mitigation information. It may be that awareness or knowledge possession among African Americans does not translate easily into action, either in the form of mitigation efforts on one's own land or for the formation of community efforts like Firewise or CWPPs.

While we acknowledge that individual landowner preferences for mitigation may vary, we also submit that specific socio-cultural practices regarding landownership rights, inhibit more socially vulnerable groups from engaging in mitigation. Specifically, the practice or system of "heir property" ownership among lower income southern landowners may work to constrain involvement in land improvement initiatives. Building on Collins' (2008a) thesis that the environmental values of distinct socio-cultural groups influence community exposure to wildland fire risk, we posit that differences in hot spot and High–Low community engagement with mitigation may be explained in part by cultural norms reifying communal ownership of land in the South.

Heir property or tenancy in common is inherited land which is passed on intestate, without clear title, typically to family members. Although such owners have legal claims to land, there are no demarcations of the land specifying what amount is held by a single individual (Dyer et al., 2009; Dyer and Bailey, 2008). With each succeeding generation, individual ownership interests shrink because of the growing number of heirs.

Mitchell (2001) estimates that 41% of African American-owned land in the southeastern U.S. is heir property, and Craig-Taylor (2000) (in Dyer and Bailey, 2008) states that heir property represents "the most widespread form of property ownership in the African American Community." But Dyer et al. (2009) caution against overestimates, arguing that few systematic investigations of heir property prevalence have been conducted because of the meticulous methodology required to classify such properties. Although much of the scholarship on heir property concentrates on southern blacks, this type of ownership is also prevalent among Appalachian whites (Deaton et al., 2009).

There are a number of problems associated with heir property and land management. Principle among these is that the lack of clear title prohibits participation in any government sponsored home improvement programs. Also, property owners cannot use heir property as collateral for a mortgage, and selling timber from such land is virtually impossible because a buyer would have to secure the consent of all heirs for a sale, and most buyers are unwilling to do so. Besides this, the lack of clear title acts as a disincentive to the improvement of real property attached to land. If a structure were remodeled, the increase in value would not accrue to the individual who paid for the upgrade, but again must be disbursed among all heirs, regardless of where they live (Dyer et al., 2009; Dyer and Bailey, 2008). In many cases, heirs may not even live in the same state as the property location. Drawing from economics, Deaton et al. (2009) argue that such impediments result in "efficiency" problems, which occur when "…the existing uses of the property result in lower net-benefits to the cotenants than might otherwise be achieved." Viewed from the lens of profit maximization, land use in such scenarios is underutilized.

We submit that heir property holders would also be less motivated to participate in wildland fire mitigation because of the communal nature of their land interest. Again, any fees, land clearing, structure preparation, or other time commitments to CWPP or Firewise would be likely be borne by the residing heir or others living closer to the property. While all heirs would not have to consent to mitigation planning, the disproportionate involvement by one or a few heirs might deter participation because of costs necessary to insulate structures or clear land either on or off one's property. Deaton et al.'s (2009) case study from Kentucky illustrates how cotenants' unwillingness to cut timber from their land had the unintentional consequence of increasing undergrowth, resulting in increased fuel loading.

Deaton et al. (2009) describe heir property management as a "tragedy of the anti commons" in that heirs of jointly held land can prevent any single heir from certain land uses, some of which would yield profits or potentially lessen hazards. In contrast to the overuse "tragedy of the commons" problem, with heir property the conflict involves under or nonuse.

Also, a key factor in mitigation success for CWPPs is collaboration with and federal agencies (U.S. Forest Service, U.S. Bureau of Land Management). Communities are expected to draw on the expertise of

[9] Personal communication (2010). Gerry Lacavera, Florida Division of Forestry.

these agencies for plan preparation and develop a trust in agency responsiveness. This type of involvement might deter southern, rural African Americans, in general (whether heir property owners or not) from participating in fire mitigation planning.

African Americans have lost land due to multiple factors, including lack of understanding of estate planning and taxation and also from various forms of discrimination perpetuated through federal agencies. The 1997 class action law suit (*Pigford versus Glickman*) initiated by black farmers alleging systematic discrimination on the part of the USDA exemplifies this latter problem and also highlights the sometimes antagonistic relationship between Southern black landowners and governmental agencies. Despite a settlement in the *Pigford* case that favored black farmers, there remains an atmosphere of mistrust and apprehension on the part of some black, Southern landowners towards the federal government and other public agencies.

Dyer and Bailey (2008) and Deaton et al. (2009) write that the drawbacks of heir property are countered by a socio-cultural understanding of extended family and its relationship to home. This landownership form fosters a collective identity, which has been a cornerstone of rural culture, especially among southern African Americans. Heir property arrangements allow cotenants to maintain strong bonds and a connection to the land, the land not *individually* owned but shared by those counted as family. Indeed, with heir property, family members can more easily establish residences by simply putting mobile homes on the land. The more rigorous process of home building is avoided: "The rural countryside of the South is dotted with such small communities of kin characterized by clusters of mobile homes and simple houses." Again, however, mobile homes are a key factor which increases social vulnerability, thus exacerbating wildland fire risk.

Our objective in highlighting heir property should not be interpreted as a fatalistic culture of poverty explanation for poor people's lack of participation in wildfire mitigation programs but rather to point out a distinct socio-cultural landownership arrangement that many help to explain land management efficacy.

This was an exploratory investigation into the relationship between social status and wildland fire risk; as such, study limitations were identified. These relate to our measurement of social vulnerability. We argued that community capacity or involvement with mitigation programs is a key factor distinguishing communities; however, the components of SOVUL (percent black, below poverty), are primarily individual level variables. While individual characteristics are important vulnerability markers, community-level variables indicating natural amenities (e.g., proportion of seasonal/recreation homes or number of new housing permits); or other types of mitigation services offered by municipalities would help to sharpen a social vulnerability index specific to wildland fire. For instance, we would expect to find positive correlations between structural safety nets identified by Collins (2008a) (fire fighting services, insurance) and community involvement in mitigation programs.

Subsequent investigations should explore the utility of community-level variables to SOVUL. Also, given the overall greater distances between hot spot clusters and these two mitigation forms, CWPPs and Firewise programs, we would recommend expanding this inquiry to include other community-based mitigation programming in the South and the inclusion of more southern states to determine whether these relationships hold across the larger region. We believe the current work provides a novel point of departure for wildland fire studies in the South and gives practical information to regional fire managers contending with both natural and social risk factors.

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