EQUITY IN WILDFIRE RISK MANAGEMENT: DOES SOCIOECONOMIC STATUS PREDICT INVOLVEMENT IN FEDERAL PROGRAMS TO MITIGATE WILDFIRE RISK?

by

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Currently, biophysical risk factors figure prominently in federal resource allocation to communities threatened by wildfire. Yet, disaster research demonstrates that socioeconomic characteristics including age, gender, poverty, race, culture, education and political influence impact disaster risk and resilience.

Consequently, this thesis evaluates whether federal wildfire program resources are reaching socially vulnerable populations. My hypothesis is that socially vulnerable populations are less likely to be involved in such mitigation efforts because of the emphasis on biophysical risk factors.

To evaluate this, biophysical and social vulnerability indicators were linked at the Census Block Group level within the state of Arizona. Regression analysis was applied to evaluate predictors of participation and inclusion in federally funded wildfire mitigation efforts.

Findings indicate that resources are focused on areas of high biophysical risk, without regard to social vulnerability. In fact, disadvantaged populations are less likely to be involved in wildfire mitigation efforts than their more affluent counterparts.

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CHAPTER I

INTRODUCTION

The increasing threat of wildfire across the United States is a symptom of shortsighted forest management and increasing human development in regions where reoccurring fire is a component of a naturally functioning ecosystem. With the increase in intensity and frequency of wildfires over the past two decades, there has been a corresponding increase in suppression costs (Dombeck *et al.*, 2004). In areas where periodic, small fires once cleared the under story of woody debris, decades of fire suppression have yielded an overstock of forest fuel for a catastrophic wildfire (Dellasala *et al.*, 2004; Hessburg *et al.*, 2005). Logging practices have also contributed to the problem by altering stand density and structure (Dombeck *et al.*, 2004). Population growth and urban expansion into forested areas is complicating the issue as more homes and lives are put at risk. An area where homes and wildland fuels meet or intermingle is commonly referred to as the Wildland Urban Interface (WUI). A recent study revealed that developed acreage in the WUI, characterized by low density residential development, has increased by approximately 50% since the 1970's. By 2030 the WUI is likely to expand an additional 10% mostly in the Intermountain West (Theobald and Romme, 2007). With climate change projected to increase wildfire risk across much of the United

States, the wildfire problem will continue to be a serious concern for communities and public lands managers (Dale *et al.*, 2001; McKenzie *et al.*, 2004).

In response, federal wildfire management policy has evolved from a command-and-control approach focused on fire exclusion and rapid suppression, to a more decentralized, proactive approach. The current approach to wildfire management is based on three main components: 1) a framework for creating Community Wildfire Protection Plans (CWPP's), 2) grant programs for wildfire mitigation activities and 3) Firewise, a national program to promote wildfire awareness and local initiatives to mitigate risk through education, outreach and technical assistance.

There has been extensive research on the biophysical factors that contribute to wildfire risk (Daniel *et al.*, 2007). Vegetation, topography, weather, and historical patterns of wildfire ignition are widely used to measure wildfire risk and identify communities-at-risk (Jakes *et al.*, 2007a). Therefore it is not surprising that these factors figure heavily in prioritizing and allocating resources to mitigation efforts. However, research from a variety of types of disasters demonstrate an increase in vulnerability linked to specific human dimensions such as, age, gender, poverty, race, culture, education and political influence.

The plight of lower-income citizens in the wake of Hurricane Katrina in 2005 underscore the differences in disaster vulnerability between those with economic and political power and those without. Research on natural disasters suggests that such disparity is evident in many types of disasters (Morrow, 1999) including wildfire (Haque *et al.*, 2007). This body of research suggests that traditional planning modes, at least with

regard to natural disasters, have failed to serve the least well off in society. Not surprisingly then, a lack of trust in public officials and institutions may prevent local actors from engaging in planning processes. Yet, researchers in disaster planning and management acknowledge the valuable expertise and contributions that even the most disenfranchised can bring to disaster planning and response (Morrow, 1999).

Consequently, the purpose of this thesis was to evaluate whether federal wildfire program resources that aim to involve local communities are reaching socially vulnerable populations. In theory, resources should be going to the most at-risk populations. My hypothesis is that socially vulnerable communities are less likely to be involved in federal program efforts than less vulnerable communities of higher socioeconomic status.

CHAPTER II

LITERATURE REVIEW

2.1 Wildfire Management Policy

First conceived in 1944, Smokey Bear and his message represent one of the most successful government public relations campaigns ever. Today his message of fire prevention is now recognized as a shortsighted and misguided policy attempt to manage wildfire risk, but during the 1940's and 50's, attitudes towards public lands were different. Many perceived public forests as sources of timber to be managed and protected from fire and there was wide support for employing a rapid, efficient, command-and-control approach to fire suppression. Today, public attitudes are more heterogeneous and our understanding of the importance of fire in natural ecosystems is more sophisticated.

In a critique of public forest management published in the mid-1980's, Allen and Gould (1986) argue that U.S. Forest Service policy is misguided in attempting to apply rational, scientific management decision processes to "wicked" public lands management problems. More recently, several social scientists who study wildfire issues described the development of the wildfire issue as the result of a "complex mix of physical, ecological, economic, and social developments" (Carroll *et al.*, 2007, p. 239). They also point out

that the wildfire issue spreads across jurisdictional boundaries and involves multiple stakeholders. Solving this issue, they continue, will require an incremental, people-centered approach rather than a single technocratic solution (Carroll *et al.*, 2007). Therefore an enduring strategy to solving the wildfire problem will require participation from those communities-at-risk, particularly where those solutions impact the social, economic and political fabric of the community.

In response to concerns about the rising costs of fire suppression, damage to forests and losses to communities, the Clinton administration initiated an effort to revamp federal wildfire management policy. That effort produced a report containing a series of recommendations and lead to the development of the Western Governor's Association (WGA) 10-Year Comprehensive Strategy for Reducing Wildfire Risk to Communities and the Environment. These documents together are referred to as the National Fire Plan (NFP) which describe the policy framework for reducing the threat of wildfire by 1) improving fire prevention and suppression 2) reducing hazardous fuels 3) restoring fire adapted ecosystems and 4) promoting community assistance (WGA, 2002). The strategies outlined in the NFP represent a significant shift from a wildfire policy focused solely on suppression to one that includes strategies for prevention and mitigation through local community involvement (Steelman *et al.*, 2004).

Some critics of environmental regulation claim that public lands management policy bears some responsibility for the wildfire problem. The regulatory framework imposed by the National Forest Management Act and the National Environmental Policy Act (NEPA) makes it difficult for federal agencies to quickly plan and administer on the

ground projects to reduce hazardous fuel buildup (Steelman and Burke, 2007). Therefore, in 2002 the Bush Administration passed the Healthy Forest Initiative (HFI) which created a class of "categorical exclusions" for qualifying fuels reduction projects, allowing such projects to bypass the more lengthy NEPA analysis and review process (Steelman and Burke, 2007). The following year Congress passed the Healthy Forest Restoration Act (HFRA). HFRA outlines a framework for collaborative wildfire planning and directs communities to develop Community Wildfire Protection Plans (CWPP) to identify critical risk factors, prioritize fuels reduction projects and establish the community's Wildland Urban Interface (WUI). HFRA also authorized $760 million annually in funding for hazardous fuels reduction projects. The act instructs agencies to direct half of that funding to projects on private lands within the CWPP's identified WUI (Steelman and Burke, 2007). The intent of the CWPP process is to engage the community in a leadership role in identifying priority areas for fuels reduction treatments. In developing CWPP's communities are also encouraged to collaborate with state and federal agencies (Newman, 2004). Community involvement and support for fuels reduction work on private lands is critical because 89% of the WUI acreage is privately owned (Theobald and Romme, 2007).

During the past several years, many communities across the U.S. have completed CWPP's, conducted fuels reduction projects using National Fire Plan (NFP) grant funds, and completed other wildfire preparedness activities (Jakes *et al.*, 2007b). Although this is encouraging, there is a lack of research to assess the effectiveness of CWPP's.

Similarly there is a lack of consensus regarding the effectiveness of thinning to reduce wildfire risk across different forest types (Daniel *et al.*, 2007).

While expressing general support for the current direction of federal wildfire policy, some see a need for greater emphasis on building community capacity to address local wildfire issues. Steelman and Burke (2007) claim that fire suppression and fuels reduction continues to be the top priority with significantly less funding being directed at the other two goals: ecosystem restoration and community assistance. Without an increase in both community economic and social capacity, communities will continue to be dependent on federal dollars to mitigate wildfire risk. Steelman and Burke call on Congress and land managers to measure progress on all the goals of the wildfire policy (Steelman *et al.*, 2004; Steelman and Burke, 2007). A 2004 report by the National Academy of Public Administration found that federal programs do not explicitly address the need to fund improvements to state and local capacities to plan and coordinate across agency boundaries to accomplish landscape scale objectives (Wise and Yoder, 2007). Participants in a series of focus groups including many stakeholders in the wildfire issue called for more community involvement and emphasized building community capacity to address wildfire risk mitigation (Burns *et al.*, 2003).

In addition to funding through various NFP grant programs, communities can access education and outreach materials and receive technical assistance through the Firewise Program which was initiated in 2001. Publications, newsletters and educational curricula are available through the program website as well as contact information for statewide Firewise program coordinators. Firewise Communities USA is a specific

component of the Firewise program that outlines a process by which participating communities become 'Firewise Recognized' by meeting program benchmarks. Specific activities vary across communities, but all recognized sites are required to create a community wildfire plan, implement at least one community wildfire preparedness project each year, spend $2 per capita annually on wildfire projects and maintain an active board of community volunteers to coordinate the plan. Recognition status is re-evaluated annually. Although recognition status does not currently confer special benefits, it could become a criterion for assistance grants or insurance coverage in the future.

The first Firewise Communities USA pilot project was initiated in six states in 2001; to date there are 288 recognized communities in 36 states. The program depends on homeowner commitment and local leadership. Although there is no size limit, in practice, most Firewise communities are neighborhood organizations or home owner associations.

Arizona was one of six states to participate in the first year of the program beginning in 2001. Since then 23 communities in Arizona have earned recognition status. Yet there are many other neighborhoods, subdivisions, and towns that have not participated who are also at risk.

Planning efforts, grant programs and the Firewise programs are available to all local communities, but state agencies can also mediate the allocation of program resources helping to direct them to high priority communities-at-risk. Research on federal funding allocation in Arizona, New Mexico and Colorado reveals that community access to federal funds for fire mitigation activities is impacted by state program organization

and prioritization based on biophysical risk factors. In New Mexico and Arizona resources are directed to high-risk communities as identified by state agencies, whereas Colorado has not prioritized particular communities and allocates a greater percentage of federal dollars to statewide programs than New Mexico or Arizona (Steelman *et al.*, 2004).

2.2 Natural Disasters and Social Vulnerability

Approaches to disaster management have changed in the past few decades away from a command-and-control top down reactionary approach to a more proactive approach focused on mitigation and preparedness. Concurrently, the field of disaster research expanded during the 80's and 90's recognizing the importance of political and social conditions as factors in community capacity to prepare and respond to a disaster (Cutter *et al.*, 2000). Research has shown that the negative impacts are a function of the social, political and economic environment as well as the natural processes that initiate them (Fothergill and Peek, 2004; Haque *et al.*, 2007). Indeed, disasters highlight a community's weaknesses, both physical and social characteristics that contribute to decreased capacity and resilience (Flint and Luloff, 2005).

2.2.1 Dimensions of Social Vulnerability

Researchers have identified multiple dimensions that contribute to a reduced capacity to "anticipate, cope with, resist, and recover from the impact of a natural hazard" (Blaikie *et al.*, 1994). The underlying factors that contribute to social vulnerability are

similar to those that produce social inequities – lack of access to resources, information, political power, limited social capital and physical frailty (Cutter *et al.*, 2003).

Poor people are more likely to suffer negative impacts including property loss, physical harm and psychological distress. Households with fewer financial resources are less likely to take steps to prepare for a disaster and more likely to have difficulty during the recovery phase (Fothergill and Peek, 2004).

At a community level, those that are well-prepared in terms of both economic and social infrastructure are more adept and responding to and recovering from natural disasters (Kumagai *et al.*, 2004a). The elderly are more likely to lack adequate economic resources and physical ability to respond effectively and they are more likely to suffer health consequences, physical harm and be slower to recover. Likewise children are more vulnerable because of their dependence on family support (Morrow, 1999). People with mental and physical disabilities are at increased risk because the will require extra assistance (Morrow, 1999). Several researches have demonstrated cultural and ethnic differences in risk perception and response (Buckland and Rahman, 1999). A lack of education, literacy and language skills can cause disadvantages in responding to a disaster when seeking information, applying for assistance or seeking post disaster employment (Morrow, 1999). Gender has also been identified as a factor in vulnerability (Cutter, 1995; Fothergill, 1996). The ability of a community to recover is related to its capacity to engage in political processes, furthermore, the disadvantages posed by income, language, ethnicity, race and political marginalization are compounded (Morrow, 1999).

Because socioeconomic status is such an important factor in vulnerability, effective emergency management needs to consider the different human dimensions as well as the biophysical causes of disaster (Buckle *et al.*, 2000). In practice, measuring, identifying and developing strategies to address social vulnerability is complex. Part of the difficulty in measuring social vulnerability is due to the fact that rather than being isolated units, populations of people are in fact members of overlapping units defined by geographic boundaries but also social and political relationships (King, 2001; Buckle *et al.*, 2000). There is also a need for further research and comparative studies to illuminate the interaction between social vulnerability and the impacts of different types of disasters (Fothergill and Peek, 2004) to inform strategies relevant to the types of disasters that communities face. Unfortunately our understanding of social vulnerability is very limited compared to our understanding of biophysical vulnerability. This is due in part to the difficulty in quantifying the social impacts of disasters (Cutter *et al.*, 2003). A better understanding of the interactions between biophysical and social vulnerabilities at multiple scales (local, regional, national) will improve our hazard assessments making them more objective and less subject to "political whim" (Cutter *et al.*, 2003, p.258).

2.2.2 Social Vulnerability in the Wildfire Context

By comparison wildfires have received less attention in the field of disaster research than hurricanes, floods, earthquakes and other catastrophic natural events; one possible explanation is the (misguided) perception that wildfires are manageable through suppression (McCaffrey, 2004). Consequently, social vulnerability in the wildfire context is perhaps underestimated. Although interest in the social dimensions of risk management

has increased, it has not been fully integrated into the management of wildfire. Much of the early research was predicated on a rational theory approach. Basically, the theory holds that once residents understand the risk they will be motivated to take action to reduce their risk (Collins, 2005). But, the way that people perceive and measure risk varies. Research has shown that attitudes towards government sponsored programs, cultural beliefs about wildfire, and past experience with wildfire are important determinants of involvement in wildfire mitigation activities. Although these findings are important, Collins asserts that the socioeconomic barriers to mitigation action have not received due attention. This is due in part to the assumption that WUI residents are comprised primarily of "amenity migrants", those that chose to live in areas most at risk to wildfire (Collins, 2005). But, many WUI residents are not "amenity migrants" and wildfire impacts can vary significantly between households within the same community. For example, renters have fewer options than homeowners, especially those homeowners with adequate insurance and the resources to rebuild or relocate (Carroll *et al.*, 2005).

Several studies have found that financial constraints limit residents' ability to take precautionary measures. An Australian study showed that people with mental or physical disabilities and those suffering from poverty are more at risk to structural fires because they are less capable of responding in an emergency and more likely to have substandard living conditions (Rhodes and Reinholtd, 1998). A survey of households in a WUI community in California found that cost was the most common barrier to taking steps to reduce their home's ignitability (Collins, 2005). Similar results were found in a study of residents living in Colorado's Front Range, where residents cited concerns about cost,

time commitment, and a lack of physical ability to implement mitigation actions (Absher and Vaske, 2007).

The findings from these academic studies are corroborated in a report on wildfire and poverty in the Western United States by Niemi and Lee (2001). The study's authors found that poor households are more likely to have inadequate self-protection for housing, limited access to health care a greater proportion of their economic assets at risk to wildfire, and decrease resiliency to recover from the impacts of a wildfire.

Poverty also has impacts at a community level. An analysis of fire district protection capability and poverty found conducted across the state of Washington found that poor households are more likely in fire districts with low response capacity (Lynn and Gerlitz, 2005). A study in Florida that sought to associate socioeconomic variables with wildfire intensity showed that counties with higher incidence of poverty had fewer ignitions, but once ignited suffered larger, more intense fires. The researchers speculate that a lack of suppression capacity may account for the finding (Mercer and Prestemon, 2005).

In addition to decreased capacity to prepare, poor communities are less likely to recover quickly from a wildfire. Where community resources are scarce these disruptions are likely to be more severe. Communities can be impacted by the disruption of social process, changes in the allocation of resources towards restoration and reconstruction projects at the expense of other community developments (Jakes, 2007).

Community responses to wildfire threat fall into two types, structural and social. Structural responses focus on biophysical aspects such as actions to reduce hazardous

fuels, apply land use regulations, enforce building codes and enhance fire suppression capacity. Social responses refer to intangible processes including planning, management, organization and decision making processes. There is a need to better understand the how socioeconomic status impacts these intangible processes (Steelman and Kunkel, 2004).

2.2.3 Indicators of Social Vulnerability in the Wildfire Context

In 2000 Case et al. (2000) suggested using Census data to model community risk to wildfire based on socioeconomic measures, specifically populations of the very old, the young and those suffering from poverty. They argue that the total social impacts would be reduced by taking a strategic approach to protecting those where the social risk is greatest. To measure social vulnerability in the wildfire context, I generated a broader list of indicators based on two previous efforts to describe social vulnerability.

Cutter et al. (2000) developed a social vulnerability index for emergency managers to use as a tool to compare risk across the United States. They started with a review of literature and through factor analysis reduced 42 unique metrics down to 11 principle factors including personal wealth, age, density of the built environment, occupation, household stock and tenancy, single-sector economic dependence, infrastructure dependence and three factors related to differences in race and ethnicity.

In another effort to build a construct of social dimensions related to wildfire risk and resilience, Evans et al., (2007) developed an Index of Community Capacity for Protection from Wildfires (ICCPW). They also conducted a review of the literature and reference some of the same research as Cutter et al. Although their index seeks to measure capacity, its inverse - lack of capacity - is closely related to social vulnerability

producing much overlap between the constructs. Like the social vulnerability index, the ICCPW includes measures of age, wealth, and employment, and ethnicity.

Table 1 describes the socioeconomic measures I chose for this project with relevant citations from the natural disaster literature. I included dimensions that were common to both indexes developed by Cutter et al. and Evans et al. (e.g. age, wealth, employment and ethnicity). I also sought measures that were readily available local scale; in this case the Census Block Group.

Table 1. Measures of Social Vulnerability.

Measure	Description	Reference
Percent Vulnerable Age	Total youth (<15 yrs) plus total elderly (>64 yrs) divided by the total population	(Aptekar and Boore, 1990; Morrow, 1999; Ngo, 2001;)
Race	Percent of population that is not one race = white	(Bolin, 1986) Peacock *et al.*, 1997; Pulido, 2000)
Single-Mother Households	Percent of households headed by a single-mother	(Cutter, 1995; Puente, 1999; Morrow, 1999)
Physical Disability	Percent of the population with a disability	(Tobin and Ollenburger, 1993; Rhodes and Reinholtd, 1998; Morrow, 1999)
Education	Percent of the population that has earned a high school diploma	(Heinz Center for Science, 2000)
Language	Percent of population that speak only English or speak English "very well" or "well"	(Buckland and Rahman, 1999)
Median Income	Household median income	(Blaikie *et al.*, 1994)
Poverty	Percent of families below the federal poverty limit	(Niemi and Lee, 2001; Fothergill and Peek, 2004)
Unemployment	Percent unemployment	(Mileti, 1999)

2.2.4 Economic Vulnerability in Rural Communities

Many of the communities at-risk to wildfire are also economically linked to the use of natural resources on adjacent public lands. For example, The Rodeo-Chediski fire in Arizona in 2002 impacted both tribal and non-tribal communities. The tribal

communities will likely suffer greater long-term economic impacts from the loss of timber resources than the non-tribal communities (Carroll and Cohn, 2003).

Flint and Luloff (2005, p.400) suggest that researchers' perspectives on natural-resource based communities and theories of social vulnerability to natural disasters both overlook the role of endogenous initiative and capacity. They identify the "traditional perspective" on natural resource-based communities which holds that they are more vulnerable to environmental and social change, economically unstable and subject to "unbalanced power relationships with external institutions and agents" But Flint and Luloff (2005) also describe recent research that reveals community initiative and capacity in developing the economic and non-economic benefits of surrounding resources (Bridger and Luloff, 1999; Luloff *et al.*, 2003). Similarly, according to Flint and Luloff (2005, p. 402) the "traditional" view in natural disaster research characterizes vulnerable communities as helpless and dependent on external resources for disaster response and recovery. But, as with economic empowerment, researchers are beginning to acknowledge the importance of "local knowledge, action, participation, and control". In conclusion Flint and Luloff (2005) call for more research that seeks to understand community capacity and how communities act in response to perceived risks.

2.2.5 Helping Agencies

Federal, state, and local agencies have an important role in assisting communities to prepare for, respond to, and recover from a disaster by in facilitating access to federal resources for groups that have been historically marginalized (Bolin and Stanford, 1998). However, for emergency managers to effectively address the peculiar needs of vulnerable

populations, they need to have data on the types of people within their communities and what types of assistance they may require (King, 2001). Such information can come from social vulnerability indicators and mapping exercises like those described above, but also through partnerships and dialogue with socially vulnerable communities.

The challenge is that the level of social and economic development generally correlates with community capacity to develop productive partnerships with government agency disaster management efforts (Buckland and Rahman, 1999). In a disaster management scenario, social capital, i.e. social networks built on trust and reciprocity, leads to more effective community response (Neal and Phillips, 1995). Localized wildfire mitigation efforts that empower communities, such as the CWPP process facilitate collaboration and can lead to increased social capital within a community (bonding capital) and between local stakeholders and outside helping agencies (bridging capital) (Jakes *et al.*, 2007a)

Research on community social reactions to wildfire highlight the importance of both types of social capital. Conflict between local and non-local entities during and after a wildfire event are more likely where there tensions between local and outside agencies already exists (Jakes, 2007). Tensions can also result from the loss of community trust in land managers' ability to mitigate wildfire risk. This trust is particularly vulnerable where past management practices and policies have led to suspicion and controversy between local and outsider interests (Mendez *et al.*, 2003; Kumagai *et al.*, 2004b) or where there are difference in culture between disaster victims and assistance agencies (Morrow, 1999). A study of community response to the Rodeo-Chediski fire in Arizona in 2002

demonstrated how the event could foster cohesion and conflict between and among local and non-local entities. Community characteristics including history, culture, and social norms created both challenges and opportunities during the fire response and the following recovery (Carroll *et al.*, 2005; Burchfield, 2007). Thus communities with high social capital are more likely to respond and recover more efficiently and effectively.

2.3 Synthesis

In summary, federal policy provides opportunities for helping agencies to engage communities in proactive efforts to reduce risk. The CWPP process, NFP grants and Firewise Communities USA program are the three main components of this policy. Research demonstrates that a suite of socioeconomic dimensions are correlated with increased vulnerability. These factors include age, race, disability, gender, political influence, poverty, education and employment. Despite this research, relatively little is known about social vulnerability in the wildfire context. Rather, the focus has been on understanding biophysical factors of risk and educating WUI residents to encourage mitigation action. This thesis seeks to assess the extent to which socially vulnerable populations are involved in each of the types of wildfire mitigation efforts. Findings from this research will help to determine if federal resources are being allocated equitably and highlight factors that may limit community capacity to engage in mitigation efforts.

CHAPTER III

MEASURES AND METHODS

Data on socioeconomic condition, wildfire risk, and mitigation activities were obtained from multiple sources. The first phase of this project involved integrating these data sources into a common unit of analysis. This phase merged overlapping data maps or layers into a single layer yielding a single data table with one record for each Census Block Group (CBG). The second phase was a statistical analysis of the data set to identify significant relationships among and between measures of socioeconomic condition, wildfire risk, and mitigation activities.

3.1 Study Area

Arizona presented an interesting case and appropriate study area for several reasons. First, the state has a diverse mix of communities including Native American, Hispanic, and so-called amenity migrants that are predominantly white, more affluent and often retirees. As well as racial and ethnic diversity, there are significant class and economic disparities; some communities are very affluent and others having high rates of unemployment and poverty. All of these communities have been evaluated by a statewide comprehensive risk assessment and many are at-risk to wildfire. Second, Arizona was one of six states to initiate the Firewise Communities USA program in 2001, a federally

funded program that recognizes community efforts to mitigate wildfire risk. As an early participant in the program, communities in Arizona have had access to the program for several years and 24 communities have participated in the program making Firewise recognition status a useful measure of wildfire mitigation activity. Although it may not be a perfect microcosm of the Western United States where wildfire management is most acute, Arizona presents many of the same types of communities and issues faced by other states.

3.2 Unit of Analysis

This project uses the Census Block Group (CBG) as the unit of analysis. The U.S. Census provides an extensive array of data types at the CBG level that are not available at the Census Block level. Other larger units such as Census Tracts, Census Designated Places or ad hoc aggregations of CBG's could mask significant socioeconomic variation within such larger units. But CBG's are not homogenous socioeconomic units either; Where CBG's are large, they may include diverse populations. My assumption is that the splitting or aggregation of populations caused by the arrangement of CBG boundaries is not biased towards over or under representing populations of specific socioeconomic characteristics.

The 2000 census divided Arizona into 3,554 CBG's. CBG's with a very low risk to wildfire based on the Arizona Statewide Comprehensive Risk Assessment conducted in 2004 were excluded from this analysis. This effectively excluded those CBG's in urban areas or other inhabited places that lack vegetation to warrant a significant wildfire

risk. CBG's were also excluded where the census was incomplete which occurred where the population count was zero or very small (< 10), but also included one CBG with a population of 48. In total 14 CBG's were excluded on the basis of incomplete information yielding a total data set of 960 records. My assumption is that the excluded CBG's represent such a small fraction of the data set that their exclusion does not bias the findings.

3.3 Biophysical Wildfire Risk Factors

Data on the biophysical wildfire risk factors were obtained from the Arizona State Land Dept., Forestry Division. To evaluate risk for communities throughout Arizona, I considered two potential sources: the Federal Register List of Communities-at-Risk (2001) and the Arizona statewide comprehensive risk assessment (2004).

The Federal Register List identifies 159 communities in Arizona and ranks each as high, medium or low risk. The list is restricted to communities that are adjacent to federal lands and identified as Census Designated Places. Many smaller, populated areas throughout Arizona are not included on the Federal Register list.

The statewide risk assessment lists 902 unique places and rates each according to several criteria described in more detail below. The assessment was produced through a partnership that included the Arizona State Land Dept., Forestry Division, USFS, BLM, NPS, FWS and BIA. Staff used digital ortho quads to identify developed areas and named unique communities using several sources including USGS names, place names and towns.

I elected to use the statewide risk assessment data because in included GIS data identifying the geographic footprint of each community. Plus, it provided data on the separate factors included in the assessment. For example, I was able to access information about the topography, forest fuels, historic fire occurrence and structural density for each community. Furthermore, the data was detailed down to a 1 km grid. In contrast, I was only able to obtain latitude and longitude coordinates identifying a point for each community on the Federal Register list and its associated risk rating of high, medium or low.

The statewide risk assessment considers several biophysical factors that relate to the probability of a fire occurrence and likelihood of damage to populated areas. These factors are weather, topography, fuels, historical fire occurrence and the presences of structures. Typically these factors are combined into an index and used to rank wildfire risk as an overall rating from low to high based on probable occurrence and likely intensity (Table 2). The statewide risk assessment also produced a simplified land hazard rating (Table 3). Rather than using the overall rating, I elected to analyze the land hazard rating and structural density rating as separate variables to be able to observe independent effects from these variables in the statistical analysis.

Table 2. Wildfire Risk Assessment Criteria – Overall Rating.

Factor	Component			Weight
Topography	Slope 60%		Aspect 40%	10%
Hazard	Fuels 50%	Fire Regime 25%	Condition Class 25%	35%
Risk				20%
Structural Density				35%

Table 3. Wildfire Risk Assessment Criteria – Land Hazard Rating.

Factor	Component			Weight
Topography	Slope 60%		Aspect 40%	10%
Hazard	Fuels 50%	Fire Regime 25%	Condition Class 25%	70%
Risk				20%

Whereas the statewide risk assessment developed land hazard and structural density ratings by community boundaries, I needed to calculate these values for each Census Block Group (CBG). Using GIS, I integrated data from the statewide risk assessment with a CBG data map layer obtained from Arizona Geographic Information Council. Specifically, I calculated the weighted average land hazard rating and structural density rating for the developed area within each CBG. Similarly I determined the maximum land hazard rating and structural density rating for each CBG.

3.4 Indicators of Socioeconomic Status

I selected a suite of socioeconomic indicators from a review of literature pertaining to social vulnerability. Data were obtained from the 2000 U.S. census and used to calculate specific measures (Table 4). Information on age, household relationship, and race was taken from Summary File 1 (SF-1) which is based on a 100% sample. Other information on education, employment status, and income was obtained from Summary File 3 (SF-3) which is calculated from a sample of the population.

Table 4. Summary of Socioeconomic Status Indicators.

Variable	Description
Percent Vulnerable Age	Total youth (<15 yrs) plus total elderly (>64 yrs) divided by the total population
Non-White	Percent of population that is not one race = white
Single-Mother Households	Percent of households headed by a single-mother
Disable	Percent of the population with a disability
Education	Percent of the population that has earned a high school diploma
English	Percent of population that speak only English or speak English "very well" or "well"
Median Income	Household median income
Poverty	Percent of families below the federal poverty limit
Unemployment	Percent unemployment

3.5 Wildfire Mitigation Activities

There are many ways that households and communities could mitigate their wildfire risk. Activities could include creating defensible space around homes by reducing buildup of flammable vegetation and debris, fitting homes with fire-resistant materials, developing evacuation plans, purchasing suppression equipment, purchasing disaster insurance or educating residents about the risks. This thesis is focused on the components of current federal wildfire management policy and is therefore limited to data on Community Wildfire Protection Plans, State Fire Assistance grant awards, and participation in the Firewise Communities USA program.

There are other grant programs to aid communities in managing wildfire risk besides the State Fire Assistance Grant program, but I was unable to obtain data on the Volunteer Fire Assistance Program (VFA), Rural Fire Assistance Program (RFA), Economic Action Program (EAP) and Community and Private Land Fire Assistance Program (CPLFA). The RFA and VFA programs continue to be funded as of 2008, but

the EAP and CPLFA programs have not been funded since 2004. While SFA grants have and continue to represent the majority of NFP grant funds expended in the state, omission of the data on the other grant programs may under-represent community involvement in grant funded wildfire mitigation projects.

For simplicity, I use the term "involved" as a generic way to describe a population that is either actively engaged in an activity, or potentially benefits from that activity such as a neighborhood that benefits from an adjacent fuels reduction project or is within the plan area of a CWPP.

3.5.1 The Firewise Communities USA Program

I obtained data on communities that have participated in the Firewise Communities USA program from the Arizona State Land Dept., Forestry Division. Staff provided a spreadsheet list of communities, dates of initiation in the program, recognition date and current status in the program. As of January 2008, 24 communities were involved in the Firewise Communities USA Program. Of those, 22 were 'recognized' in 2008; one is inactive and one is in the process of earning recognition status. Timber Ridge, near Prescott, was the first community in Arizona to receive Firewise recognition; it earned recognition status in 2002.

To determine geographic location, I attempted to match recognized communities to the list of communities-at-risk from the statewide risk assessment and the Federal Register List. I was only able to match about half of the recognized communities in the data set. To locate the others, I conducted an Internet search using Google. By searching using the community name and/or the name of the lead organization, often a homeowners

association, I was able to identify approximate locations for the remaining communities and use Google Earth to obtain latitude and longitude coordinates to create point locations in a GIS data map layer. Lacking information about the geographic footprint of the group of residents that comprise the Firewise community, I calculated a ¾ mile buffer zone as an estimate. I then assigned Firewise involvement to CBG's that contained a Firewise community or intersected with this ¾ mile buffer. The Arizona State Firewise coordinator inspected a series of maps for each community and confirmed that my methodology produced a reasonable approximation for the location of each recognized community.

3.5.2 Community Wildfire Protection Plans (CWPP)

As of January 2008 there were 16 CWPP's in place throughout Arizona. As well, there were seven plans in various stages of development. These unfinished plans are not included in this analysis. All of the CWPP's are variable in both geographic extent and scope. The largest encompasses all of Graham County and the smallest includes just a few, small communities. The earliest plans were adopted in 2004.

I estimated the geographic boundaries of the CWPP plan area from a visual inspection of a map provided by the Arizona State Lands Dept., Forestry Division. Using the map as a reference, I manually digitized CWPP boundaries into a GIS data map layer. Then I overlaid CWPP layer with the CBG map layer. Then, I manually linked CBG's to CWPP's where a majority of the developed area from the CBG fell within a CWPP plan area. Each CBG was determined to be either in a CWPP plan area, or not in a CWPP plan area.

3.5.3 State Fire Assistance (SFA) Grants

The Arizona State Land Dept., Forestry Division provided data on SFA grants awarded from 2001 to 2007. Grants were awarded for fuels reduction work, outreach and education, and planning. The data set included the community name and sponsoring organization, awarded amount and a brief description of the purpose of the grant. In total across the six year period approximately $19 million was awarded with the bulk of funding for fuels reduction work (85.1%) (Table5).

Table 5. SFA Grant Totals by Activity, Arizona, 2001-2007

Grant Activity	Total Amount	Percent
Education and Awareness	$ 1,904,385	10.0%
Fire Suppression Equipment	$ 131,937	0.7%
Fuels Reduction Projects	$ 16,272,369	85.1%
Planning	$ 182,390	1.0%
Restoration	$ 628,798	3.3%
Total	$ 19,119,879	100.0%

Source: Arizona State Lands Dept. Forestry Division

SFA grants are available to Western States on a competitive basis. SFA grants are intended to support activities related to fuels reduction, education, and planning. Applicants must demonstrate a 50:50 match which can be a hard cash match or through in-kind contributions of labor or donated equipment. Grants are more competitive if they will produce measurable outcomes, include collaboration, support an existing community wildfire plan and are likely to be enduring.

Using GIS, I linked the communities-at-risk data map layer from the Statewide Risk Assessment, the SFA grants data table. Some grants could not be joined to specific community where the community was listed as an entire county or in a couple instances as "statewide". These grants and a few others that could not be associated to a specific

community from the Statewide Risk Assessment were excluded. These excluded grants represent approximately 20% of the total dollar amount awarded and could bias the findings if such grants were more likely to benefit populations of a particular socioeconomic status.

To associate SFA grant awards with Census Block Groups (CBG's), I overlapped the communities map layer and the CBG map layer and joined the data sets. Where a community which had benefited from one or more SFA grants intersected a CBG, I coded the CBG as being "involved" with an SFA grant project, all other CBG's were coded "not involved". Limitations in the data set precluded a more precise methodology; detailed geographic information to specific populations would reduce measurement error. However, my assumption is that the methodology applied does not bias the findings along socioeconomic dimensions.

3.6 Limitations

Limitations are inherent in this study due to the nature and quality of the data. Perhaps the most significant, which has been mentioned already, is the omission of grant data from other wildfire mitigation grant programs. Particularly the Volunteer Fire Assistance Program (VFA) and the Rural Fire Assistance Program (RFA). Both of those programs are targeted towards increasing the capacity of communities that lack adequate resources for wildfire suppression. Had these data been available, it might alter the results as poor, rural communities might be more likely to be involved in the VFA and RFA programs.

A second limitation is the difficulty in using Census Block Groups (CBG's) as the unit of analysis. CBG's in Arizona vary widely in area and population. Therefore measurement errors in calculating socioeconomic characteristics and biophysical traits are more likely in the larger CBG's. A related limitation is the use of structural density from the Statewide Risk Assessment. Density per developed area within a CBG is not the same as the size of a community. Since CBG's vary so widely in size and most divide rather than encompass cities or towns, the complexity of the task prohibited me from creating a community size variable for each CBG. It is likely that the size of a community or proximity to an urban center is a significant variable, but its effect will have to be estimated qualitatively from the maps.

It is difficult to estimate the impacts of potential measurement errors, but I am assuming that they do not bias the results as they are not likely to systematically shift the measurements of key variables.

Lastly, data freshness could be an issue for this study. Data used during this study were collected and accumulated over a period of approximately nine years beginning with the data from the U.S. census and ending with the most recent update of Firewise recognized communities in January 2008. According to U.S. Census Bureau estimates, between 2000 and 2006 Arizona's population increased by 20.2% compared to a growth rate of 6.4% for the U.S.

3.7 Analysis

The statistical analysis consists of two phases, first an inspection of collinear relationship between indicators of socioeconomic status, then regression analysis to explore relationships between socioeconomic status and involvement in wildfire mitigation activities.

When two or more independent variables are highly correlated it is difficult to use statistical methods to discern the relative influence of each on the dependent variable. Therefore when using a set of multiple dependent variables it is common for researchers to attempt to reduce their suite of measures to some smaller number that still serves as a proxy for the underlying factor of interest. Many indicators of social vulnerability are highly correlated such as poverty and median income indicating they are measuring a similar community characteristic. Others are less so, such as disability and language. Using SPSS, I calculated Pearson's correlation coefficients for each of the possible bivariate relationships within the suite of social vulnerability measures. I then used these results to group indicators that were highly correlated and interpret the findings from the logistic regression analysis.

A binary logistic regression analysis is used to assess the ability of an independent variable predict the dependent variable when the dependent variable is dichotomous. For this study the dependent variables are involvement in 1) The Firewise Communities USA program 2) An established CWPP and 3) A State Fire Assistance grant funded project during 2001-2007. In a binary logistic analysis the independent variable is labeled the predictor and the dependent variable the outcome. Including multiple predictors in the

regression can reveal the effects of multiple variables to evaluate the relative influence of different predictors and determine statistical levels of significance for these affects.

CHAPTER IV

FINDINGS

The findings section has two components. First, I report on correlations between indicators of socioeconomic status. Then, I describe the relationships between biophysical and socioeconomic characteristics and the likelihood of involvement with wildfire mitigation activities. For each wildfire mitigation activity, I use a logistic regression to determine if biophysical risk factors for wildfire and socioeconomic status predict involvement in wildfire mitigation activities.

4.1 Correlations Between Socioeconomic Indicators

Pearson's correlation coefficients indicate that the indicators of socioeconomic status in this data set cluster into one main factor that includes seven of the nine indicators (Table 6). The main group includes the measures of single-mother households, poverty, education, race, unemployment, median income, and language. Within the main group, single-mother households, poverty and education are the most highly correlated with each other and other indicators in the group. This indicates that one of these measures would serve as the best proxy for the factor as a whole. Conversely, English was the least correlated variable, but still highly correlated with education.

The percent of people with disabilities and the percent vulnerable age population each represent two additional separate factors. While there is a correlation between these indicators and each other as well as some correlations with the indicators in the main group, the coefficients are less indicating that they are measuring a different dimension of the overall concept of social vulnerability.

Table 7 provides specific Pearson's correlation coefficients for each of the bivariate correlations and two-tailed test for significance.

Table 6. Social Vulnerability Indicators Grouped into Factors Based on Collinear Relationships.

Group	Variable	Internal Collinearity
Factor 1	Single-Mother Households	Strong
	Poverty	Strong
	Education	Strong
	Non-White	Moderate
	Unemployment	Moderate
	Median Income	Moderate
	English	Weak
Factor 2	Percent Vulnerable Age	-
Factor 3	Disabled	-

Based on these findings, I conducted multiple logistic regression analysis, each using a different set of factors or variables. A comparison of these different models and their significance is discussed in the next section.

Table 7. Pearson's Correlation Coefficients Between Indicators of Socioeconomic Status.

		Single-Mother Households	Poverty	Education	Non-White	Unemploy-ment	Median Income	English	Vulnerable Age	Disabled
Single-Mother Households		**1**	**.723****	**-.617****	**.833****	**.602****	**-.512****	-.367**	-.205**	0.028
	p value		0	0	0	0	0	0	0	0.391
Poverty		**.723****	**1**	**-.654****	**.743****	**.628****	**-.638****	-.451**	-.071*	.170**
	p value	0		0	0	0	0	0	0.027	0
Education		**-.617****	**-.654****	**1**	**-.666****	**-.531****	**.645****	**.733****	0.029	-.292**
	p value	0	0		0	0	0	0	0.374	0
Non-White		**.833****	**.743****	**-.666****	**1**	**.620****	-.497**	-.422**	-.138**	0.055
	p value	0	0	0		0	0	0	0	0.09
Unemployment		**.602****	**.628****	**-.531****	**.620****	**1**	-.449**	-.393**	-.127**	.098**
	p value	0	0	0	0		0	0	0	0.002
Median Income		**-.512****	**-.638****	**.645****	-.497**	-.449**	**1**	.377**	-.130**	-.444**
	p value	0	0	0	0	0		0	0	0
English		-.367**	-.451**	**.733****	-.422**	-.393**	.377**	**1**	.075*	-.067*
	p value	0	0	0	0	0	0		0.019	0.038
Vulnerable Age		-.205**	-.071*	0.029	-.138**	-.127**	-.130**	.075*	**1**	.377**
	p value	0	0.027	0.374	0	0	0	0.019		0
Disabled		0.028	.170**	-.292**	0.055	.098**	-.444**	-.067*	.377**	**1**
	p value	0.391	0	0	0.09	0.002	0	0.038	0	

**. Correlation is significant at the 0.01 level.
*. Correlation is significant at the 0.05 level.

4.2 Frequency of Wildfire Mitigation Activities

State Fire Assistance (SFA) Grants were the most common type of activity within this data set (Table 8). Over half (51.6%) of the Census Block Group's in the data set were associated with at least one such project between 2001 and 2007. About a third (27%) of the CBG's were within a CWPP plan area. However, participation in the Firewise Communities USA program was very rare. Only 5.4% of the CBG's in the data set were associated with a Firewise Recognized Community.

Table 8. Frequency of Wildfire Mitigation Activities by Census Block Group (CBG).

Wildfire Mitigation Activity	CBG's Involved	Percent of Total*
CWPP	204	27.0%
SFA Grant Project	327	51.6%
Firewise Recognized Community	49	5.4%

*n=960 Census Block Groups

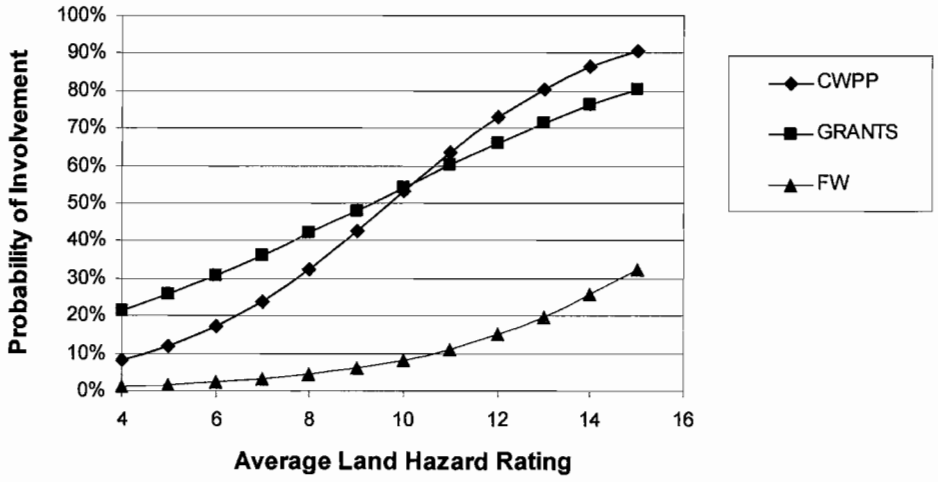
4.3 Biophysical Factors

4.3.1 Land Hazard Rating

The average land hazard rating variable was a consistent and substantial predictor of involvement in each of the three wildfire mitigation activities. Across multiple logistic regression analyses with different combinations of variables, the beta-1 coefficients for the average land hazard variable were stable. In every case an increase in the average land hazard was positively correlated with an increase likelihood of involvement in the wildfire mitigation activity. Figure 1 graphically represents how changes in the average land hazard rating are correlated with probability of involvement for a hypothetical CBG

with mean values for each of the other variables in the analysis. Involvement in the Firewise program was the most sensitive to the land hazard rating with a predicted 27-fold increase across the range of land hazard ratings. The likelihood of involvement in a CWPP increased 11-fold from the lowest to the highest average land hazard rating and the likelihood of an SFA grant project increased by a factor of 3.8.

Figure 1. Relationship Between Land Hazard Rating and Probability of Involvement in Three Types of Wildfire Mitigation Activities.

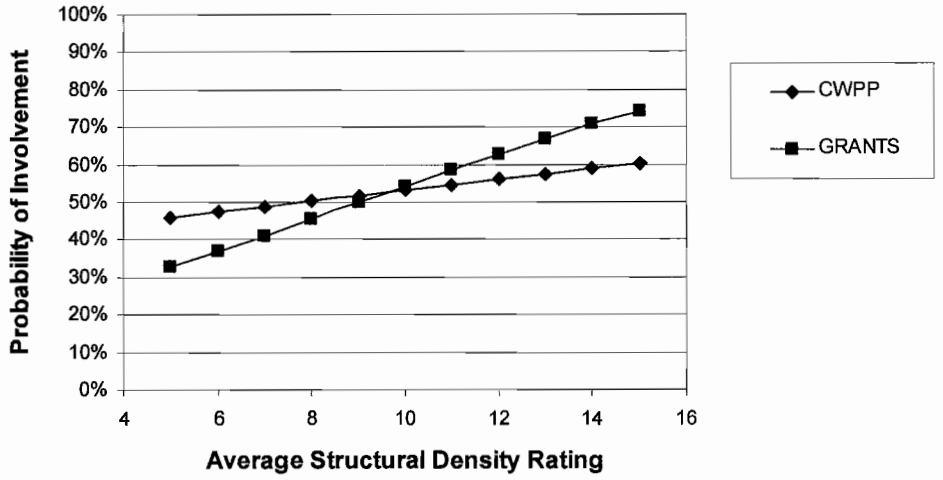


4.3.2 Structural Density

Similar to the average land hazard rating, the structural density rating was positively correlated with an increase in the likelihood of involvement in a CWPP and an SFA grant project. However, the land hazard rating was not statistically significant in predicting participation in the Firewise Communities USA program. Compared to the land hazard rating, the probability of involvement was less sensitive to changes in the

structural density variable. Figure 2 graphically represents how the probability of involvement changes across the range of average structural density ratings. From low to high average structural density the likelihood of involvement in an SFA grant project increases by a factor of 2.7, but the predicted likelihood of being involved in CWPP only increases by a factor of 1.3.

Figure 2. Relationship Between Structural Density and Probability of Involvement in CWPP's and SFA Grants.



4.4 Socioeconomic Factors

The analysis of the socioeconomic factors is more complex than the biophysical factors because there are more variables, many of which are highly correlated. Recall that the findings from the bivariate correlations between measures of social vulnerability indicate three principle factors (Table 6). Factor 1 consists of seven measures that are highly correlated. The other two factors are the percent vulnerable age variable and the

percent disability variable. I conducted multiple logistic regression analyses with variables from each factor to identify consistent and substantial correlations between socioeconomic status and likelihood of involvement in each wildfire mitigation activity.

4.4.1 Community Wildfire Protection Plans (CWPP)

Several socioeconomic variables were correlated with involvement in a CWPP; the nature of the correlations indicates that socially vulnerable populations are less likely to be involved in a CWPP. Table 9 lists the results of several different logistic regression models; the beta-1 coefficients indicate the direction of the correlation. Within the 1st factor, percent single-mother households, percent poverty, percent non-white and percent unemployed were negatively correlated with involvement in a CWPP (Table 9). CWPP involvement was positively correlated with the percent of the population with a High School Diploma and percent English speaking households. There was not a statistically significant relationship with the median income variable. The percent of vulnerable age residents in the population was negatively correlated with involvement in a CWPP and the 3rd factor, percent residents with a disability, did not have a statistically significant relationship with CWPP involvement.

Figures 3-7 illustrate the disparity between populations with different socioeconomic characteristics by isolating a single socioeconomic variable and depicting the predicted likelihood of involvement in a CWPP as the average land hazard rating increases. Three populations are depicted for each variable; a population with the mean value, a population at plus one standard deviation and one at minus one standard deviation for the variable. The graphs show that social vulnerability measured by poverty,

race, education, language or employment status is correlated with a decreased likelihood of involvement in a CWPP.

Table 9. Logistic Regression Results for Multiple Models to Predict Involvement in a CWPP.

Predictor Variable		Model							
		1	2	3	4	5	6	7	8
Single-Mother Households	Beta - 1	**0.102**						**-0.106**	
	p value	0.004						0.000	
Poverty	Beta - 1	-0.020	**-0.054**						
	p value	0.163	0.000						
Education	Beta - 1	**0.035**					**0.058**		
	p value	0.016					0.000		
Non-White	Beta - 1	**-0.047**		**-0.038**					
	p value	0.000		0.000					
Unemployment	Beta - 1	-0.047							**-0.168**
	p value	0.195							0.000
Median Income	Beta - 1	**-0.040**			0.009				
	p value	0.000			0.106				
English	Beta - 1	0.058				**0.167**			
	p value	0.100				0.000			
Percent Vulnerable Age	Beta - 1	**-0.040**	**-0.032**	**-0.035**	**-0.032**	**-0.038**	**-0.033**	**-0.039**	**-0.036**
	p value	0.000	-0.001	0.000	0.001	0.000	0.000	0.000	0.00
Disability	Beta - 1	-0.024	-0.001	-0.010	-0.008	0.000	0.017	-0.007	-0.005
	p value	0.108	0.938	0.368	0.525	0.980	0.134	0.519	0.68
Land Hazard (Avg)	Beta - 1	**0.428**	**0.460**	**0.487**	**0.410**	**0.398**	**0.411**	**0.454**	**0.459**
	p value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Structural Density (Avg)	Beta - 1	**0.058**	**0.081**	**0.076**	**0.102**	**0.092**	**0.063**	**0.110**	**0.094**
	p value	0.046	0.002	0.006	0.000	0.000	0.018	0.000	0.00
Constant	Beta - 1	-8.118	-2.737	-2.254	-3.628	-19.191	-7.913	-2.455	-2.652
	p value	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.00

Bold text indicates statistically significant correlations.

Figure 3. Probability of Involvement in a CWPP as a Function of the Average Land Hazard Rating and Percent Poverty.

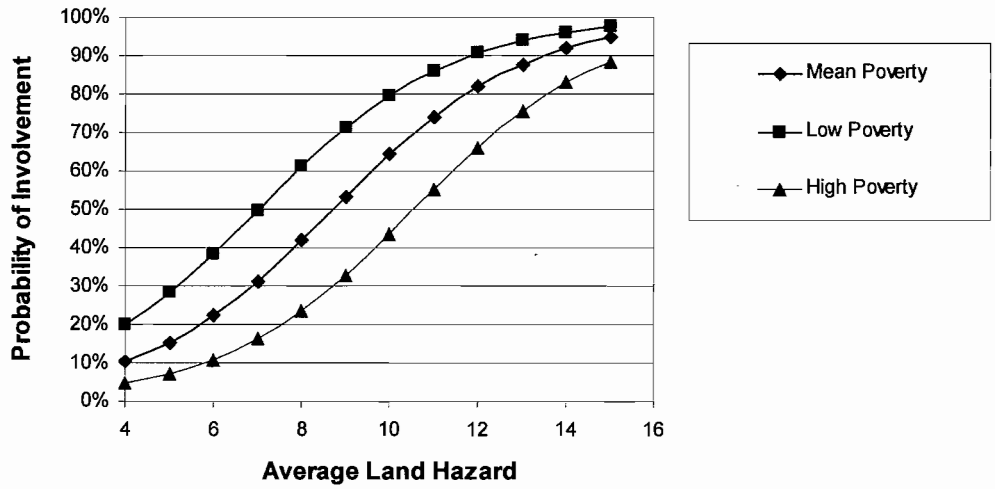


Figure 4. Probability of Involvement in a CWPP as a Function of the Average Land Hazard Rating and Percent Non-White Residents.

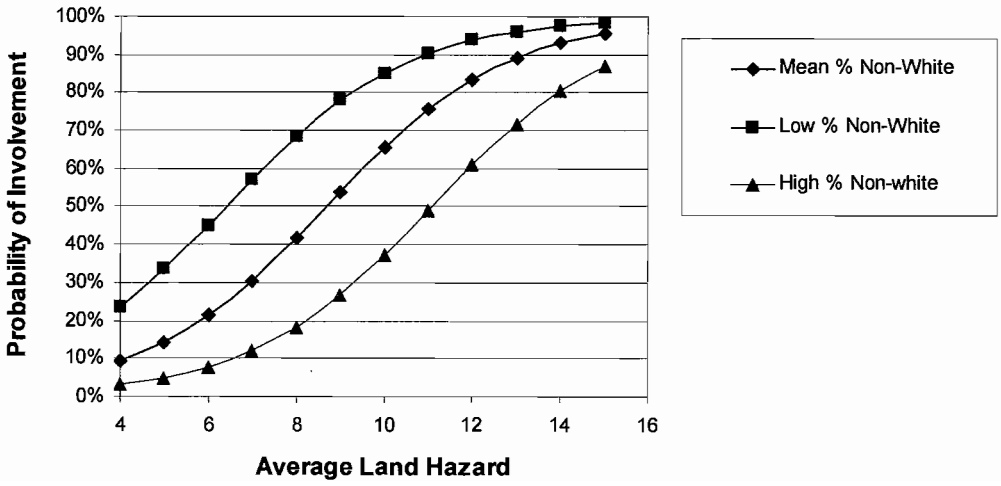


Figure 5. Probability of Involvement in a CWPP as a Function of the Average Land Hazard Rating and Percent with a High School Diploma.

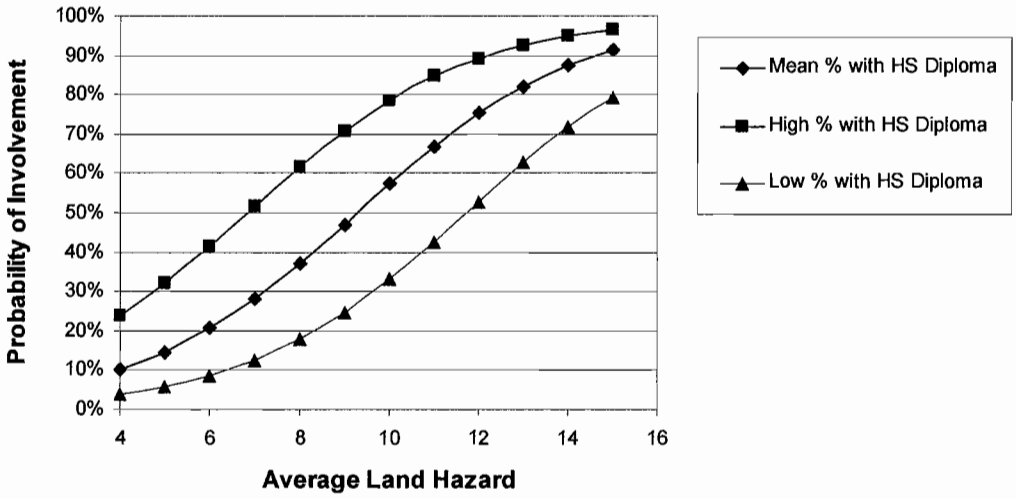


Figure 6. Probability of Involvement in a CWPP as a Function of the Average Land Hazard Rating and Percent English Speaking Households.

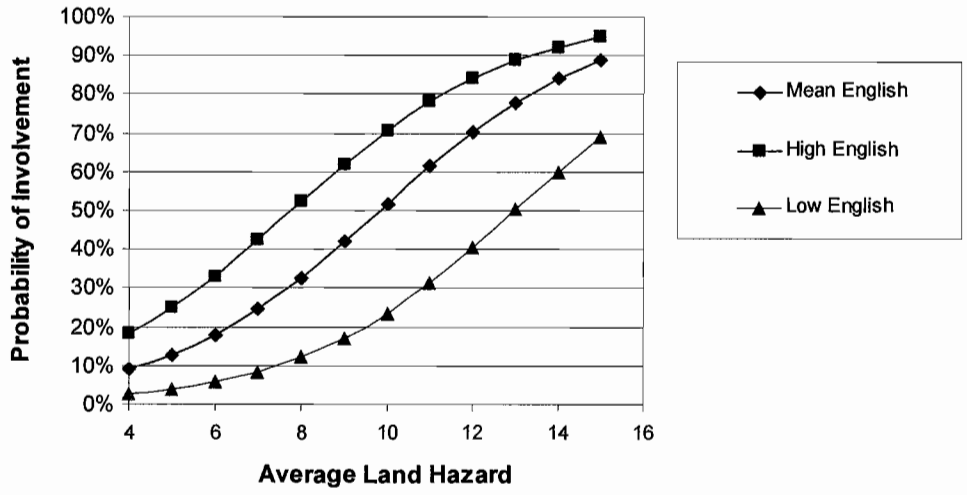
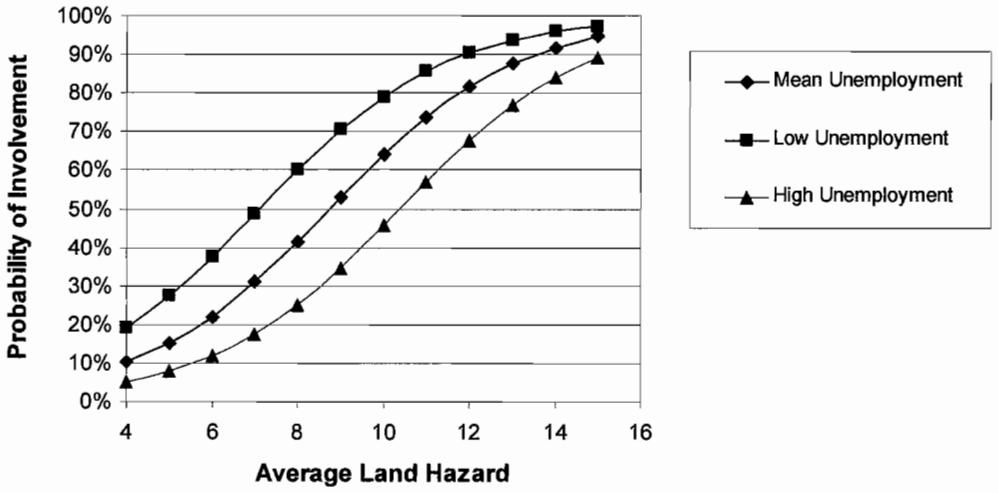
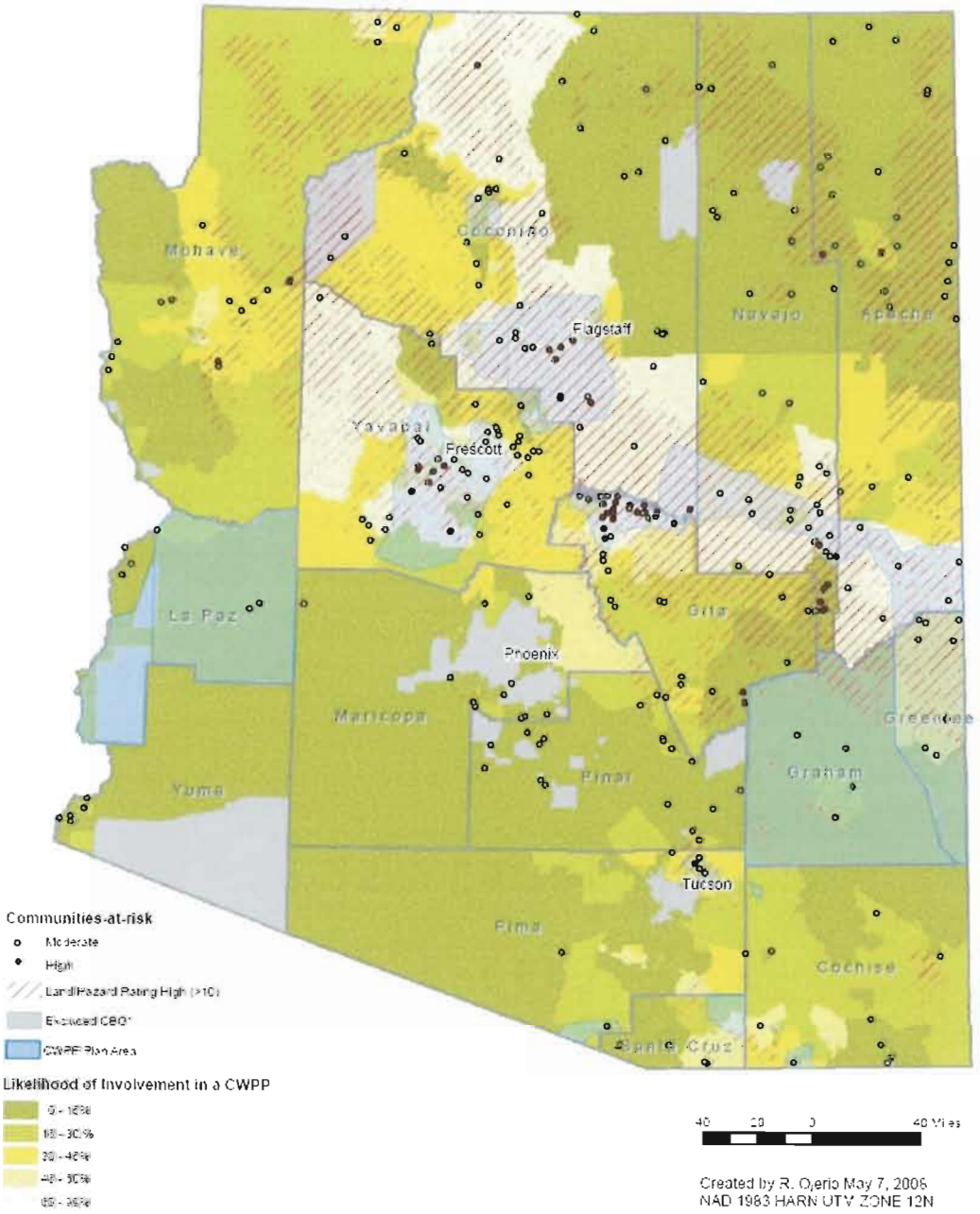


Figure 7. Probability of Involvement in a CWPP as a Function of the Average Land Hazard Rating and Percent Unemployment.



Mapping the results of the logistic regression model highlights locations where high biophysical risk to wildfire coincides with a low predicted likelihood of involvement with a CWPP. Map 1 illustrates the probability of involvement by CBG based on a statistical model that includes all of the biophysical and social variables (Model 1, Table 9). Communities-at-risk that are not within a CWPP plan area are located in high fire hazard areas in the northeast corner of the state on tribal lands in Navajo and Apache Counties as well as the eastern edge of Gila County and southern tip of Apache County.

Map 1. CWPP Plan Areas and Likelihood of Involvement by Census Block Group.



* Excluded Census Block Groups where Census data is incomplete or the risk and hazard rating is very low (<4)

4.4.2 State Fire Assistance (SFA) Grants

Similar to the findings for involvement in a CWPP, socioeconomic status was a significant predictor of involvement in an SFA grant project. Table 10 lists the results of several different logistic regression models; the beta-1 coefficients indicate the direction of the correlation. Within the 1st factor, poverty, the percent unemployment and the percent non-white residents were negatively correlated with involvement in a grant project. Median income, the percent English speaking households and the percent with a high school diploma were positively correlated with involvement in a grant project. The second factor, percent of residents of vulnerable ages, was negatively correlated, but there was no statistically significant relationship between the percent of the population with a disability and the likelihood of involvement in a grant project.

Figures 8-12 illustrate the disparity between populations with different socioeconomic characteristics by isolating a single socioeconomic variable and depicting the predicted likelihood of involvement in an SFA grant project as the average land hazard rating increases. The graphs show that social vulnerability measured by poverty, race, education, language or employment status is correlated with a decreased likelihood of involvement in an SFA grant funded project. Compared to the findings from CWPP involvement, there is less of a disparity along the socioeconomic dimensions. The greatest disparity in predicted involvement is indicated by the percent non-white residents (Figure 9).

Table 10. Logistic Regression Results for Multiple Models to Predict Involvement in SFA Grant Funded Projects.

Predictor Variable		Model							
		1	2	3	4	5	6	7	8
Single-Mother Households	Beta - 1	**0.094**						**-0.035**	
	p value	0.000						0.004	
Poverty	Beta - 1	-0.009	**-0.023**						
	p value	0.425	0.000						
Education	Beta - 1	0.019					**0.021**		
	p value	0.067					0.000		
Non-White	Beta - 1	**-0.026**		**-0.016**					
	p value	0.000		0.000					
Unemployment	Beta - 1	-0.006							**-0.062**
	p value	0.826							0.002
Median Income	Beta - 1	0.004			**0.015**				
	p value	0.536			0.002				
English	Beta - 1	-0.028				**0.023**			
	p value	0.116				0.049			
Percent Vulnerable Age	Beta - 1	**-0.044**	**-0.048**	**-0.050**	**-0.046**	**-0.048**	**-0.050**	**-0.051**	**-0.049**
	p value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Disability	Beta - 1	-0.001	-0.007	-0.010	0.000	-0.011	0.000	-0.010	-0.009
	p value	0.926	0.481	0.276	0.967	0.240	0.996	0.292	0.31
Land Hazard (Avg)	Beta - 1	**0.246**	**0.237**	**0.246**	**0.232**	**0.209**	**0.208**	**0.228**	**0.235**
	p value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Structural Density (Avg)	Beta - 1	**0.178**	**0.203**	**0.203**	**0.206**	**0.211**	**0.201**	**0.215**	**0.211**
	p value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Constant	Beta - 1	-1.114	-1.812	-1.579	-2.996	-4.165	-3.689	-1.752	-1.828
	p value	0.432	0.000	0.000	0.000	0.000	0.000	0.000	0.00

Bold text indicates statistically significant correlations.

Figure 8. Probability of Involvement in an SFA Grant as a Function of the Average Land Hazard Rating and Percent Poverty.

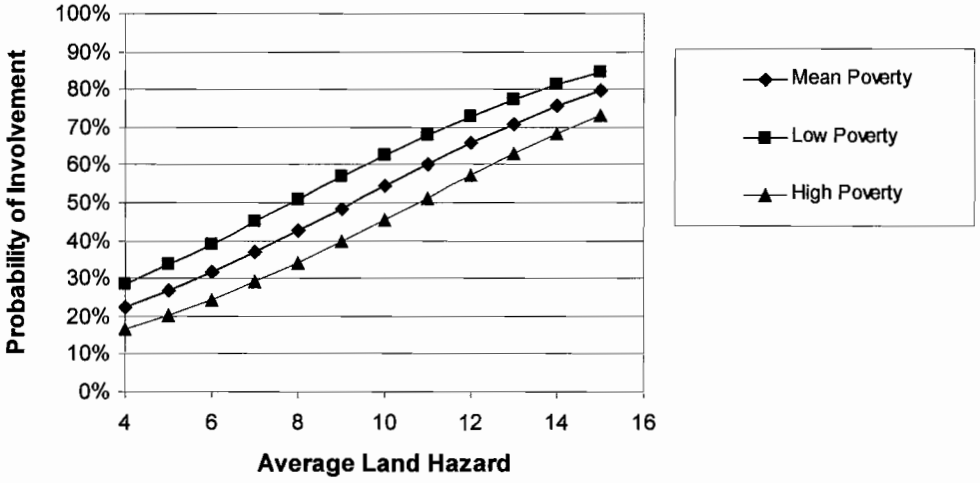


Figure 9. Probability of Involvement in an SFA Grant as a Function of the Average Land Hazard Rating and Percent Non-White Residents.

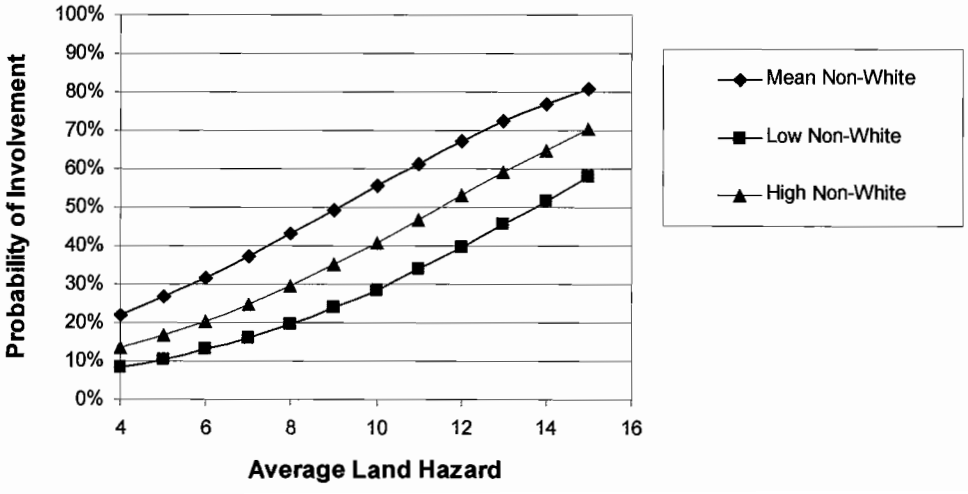


Figure 10. Probability of Involvement in an SFA Grant as a Function of the Average Land Hazard Rating and Percent with a High School Diploma.

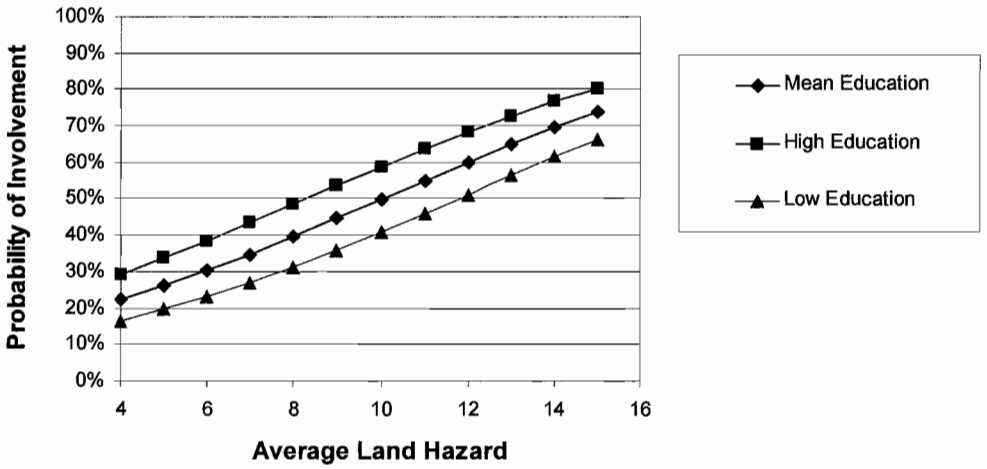


Figure 11. Probability of Involvement in an SFA Grant as a Function of the Average Land Hazard Rating and Percent English Speaking Households.

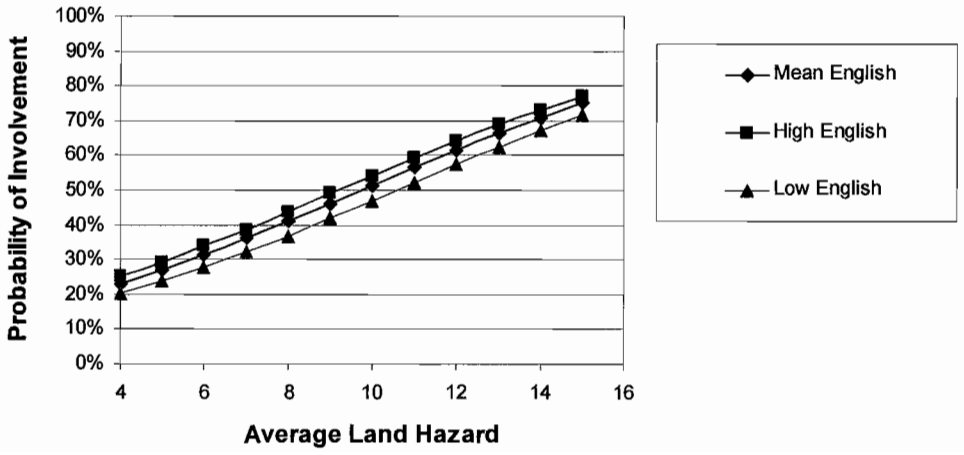
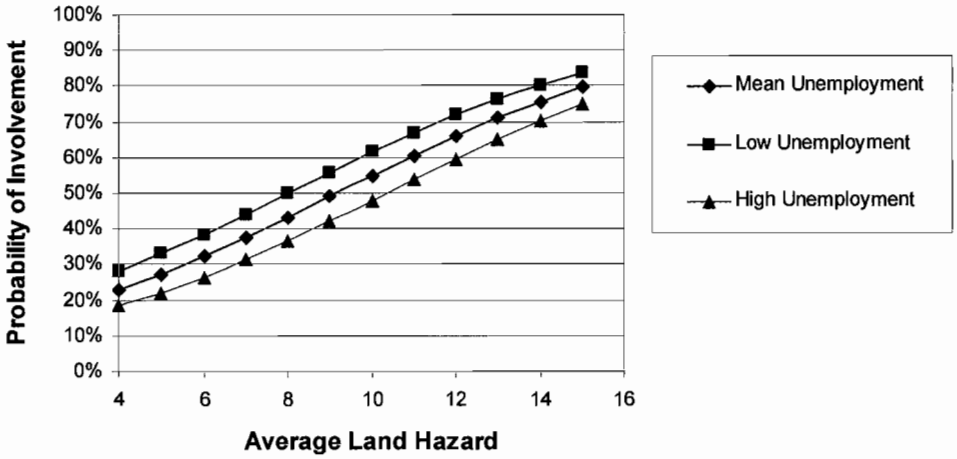
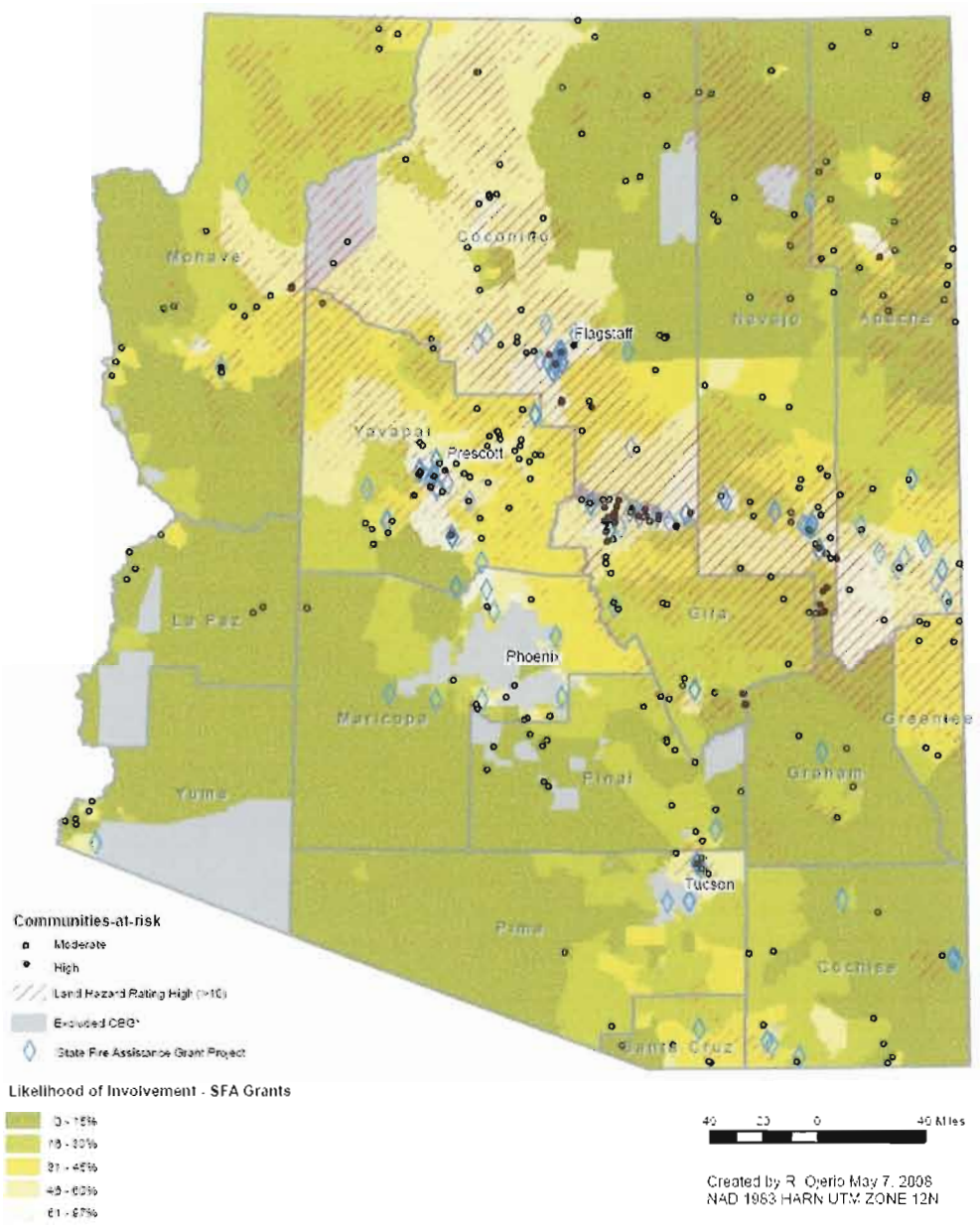


Figure 12.Probability of Involvement in an SFA Grant as a Function of the Average Land Hazard Rating and Percent Unemployment.



Using the statistical model with all of the biophysical and socioeconomic variables (Model 1, Table 10), I calculated the predicted likelihood of involvement in an SFA grant project for each CBG in the data set. Map 2 illustrates the distribution of SFA grant projects along with these results. The map highlights areas where high biophysical risk coincides with a low likelihood of involvement in an SFA grant project. Such areas include communities on tribal lands in the northeastern part of the state in Apache and Navajo Counties and a few communities on the eastern edge of Gila County and southern Tip of Apache County.

Map 2. SFA Grant Project Locations and Likelihood of Involvement by Census Block Group.



* Excluded Census Block Groups where Census data is incomplete or the max. land hazard rating is very low (<4)

4.4.3 The Firewise Communities USA Program

Several indicators of socioeconomic status were significant predictors of involvement in the Firewise Communities USA program. Table 11 lists the beta-1 coefficients for several logistic regression models using different combinations of the socioeconomic variables. These results show that poverty, the percent non-white residents, percent single-mother households and percent unemployment were all negatively correlated with involvement in the Firewise program. The percent with a high school diploma, percent English speaking households and median income were positively correlated with involvement in the Firewise program.

When all of the variables from factor 1 are included in the regression only the percent non-white residents is statistically significant indicating that race is the most substantial predictor of involvement in the Firewise program.

Figures 13-17 illustrate the results of the statistical models for each of five socioeconomic indicators. In each instance the predicted likelihood of involvement in the Firewise program increases with an increase in land hazard rating. However, those communities with higher social vulnerability as indicated by poverty, race, education, language and employment status are less likely to participate in the program compared to populations that are less socially vulnerable. Note that the difference in predicted involvement between populations of high vs. low social vulnerability is much greater for the Firewise program than with CWPP's and the SFA grant projects.

Table 11. Logistic Regression Results for Multiple Models to Predict Involvement in the Firewise Communities USA Program.

Predictor Variable		Model							
		1	2	3	4	5	6	7	8
Single-Mother Households	Beta - 1	0.055						**-0.168**	
	p value	0.456						0.000	
Poverty	Beta - 1	-0.011	**-0.071**						
	p value	0.733	0.000						
Education	Beta - 1	0.047					**0.075**		
	p value	0.110					0.000		
Non-White	Beta - 1	**-0.089**		**-0.081**					
	p value	0.005		0.000					
Unemployment	Beta - 1	-0.107							**-0.261**
	p value	0.218							0.000
Median Income	Beta - 1	0.000			**0.029**				
	p value	0.379			0.001				
English	Beta - 1	-0.093				**0.132**			
	p value	0.097				0.013			
Percent Vulnerable Age	Beta - 1	-0.007	0.011	-0.003	0.021	0.013	0.013	0.000	0.006
	p value	0.648	0.392	0.828	0.106	0.326	0.270	0.981	0.63
Disability	Beta - 1	0.007	0.009	-0.001	0.013	0.000	0.023	0.003	0.008
	p value	0.708	0.652	0.975	0.508	0.997	0.157	0.859	0.65
Land Hazard (Avg)	Beta - 1	**0.335**	**0.376**	**0.349**	**0.385**	**0.342**	**0.333**	**0.370**	**0.389**
	p value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Structural Density (Avg)	Beta - 1	0.008	0.015	0.027	0.028	0.034	-0.005	0.045	0.025
	p value	0.869	0.732	0.563	0.520	0.435	0.918	0.314	0.570
Constant	Beta - 1	2.331	-5.193	-3.931	-7.902	-18.606	-12.098	-4.639	-5.049
	p value	0.662	0.000	0.000	0.000	0.000	0.000	0.000	0.00

Figure 13. Probability of Involvement in the Firewise Program as a Function of the Average Land Hazard Rating and Percent Poverty.

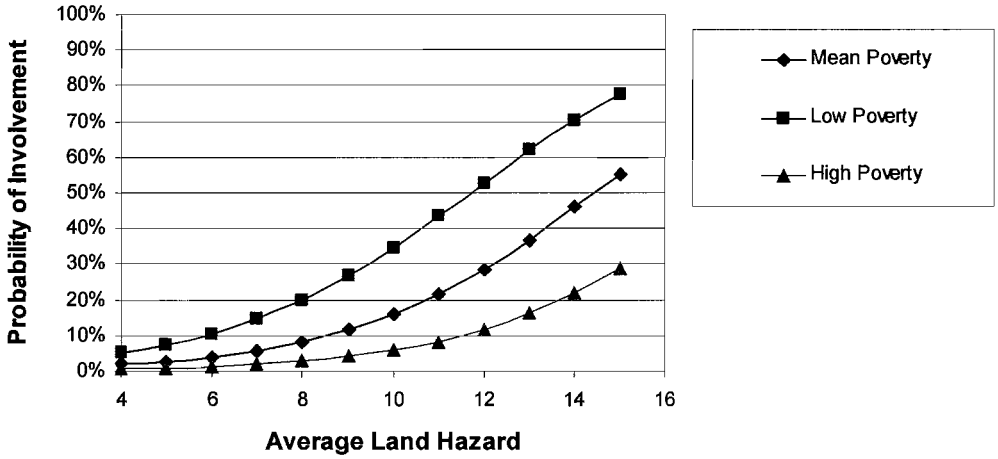


Figure 14. Probability of Involvement in the Firewise Program as a Function of the Average Land Hazard Rating and Percent Non-White Residents.

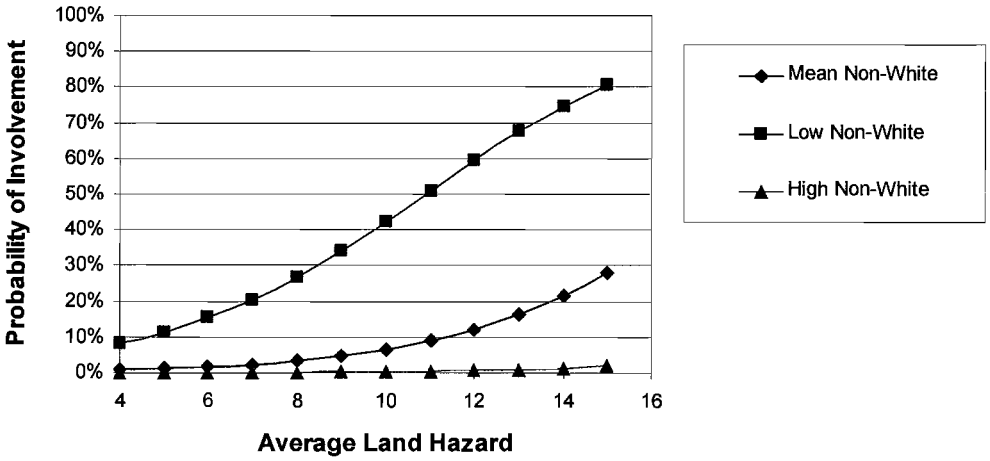


Figure 15. Probability of Involvement in the Firewise Program as a Function of the Average Land Hazard Rating and Percent with a High School Diploma.

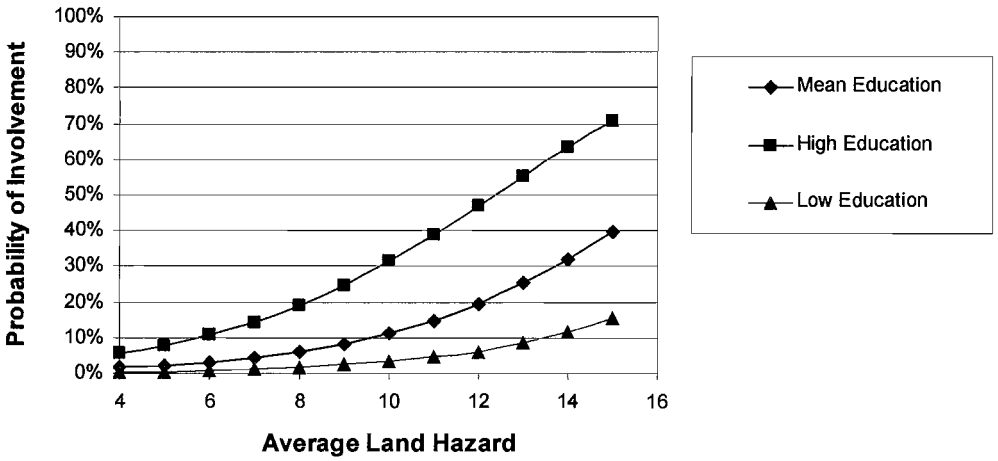


Figure 16. Probability of Involvement in the Firewise Program as a Function of the Average Land Hazard Rating and Percent English Speaking Households.

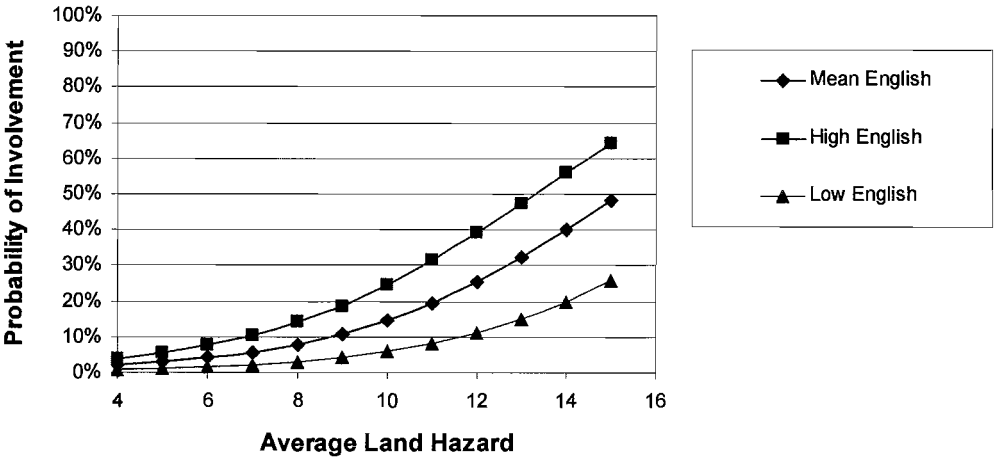
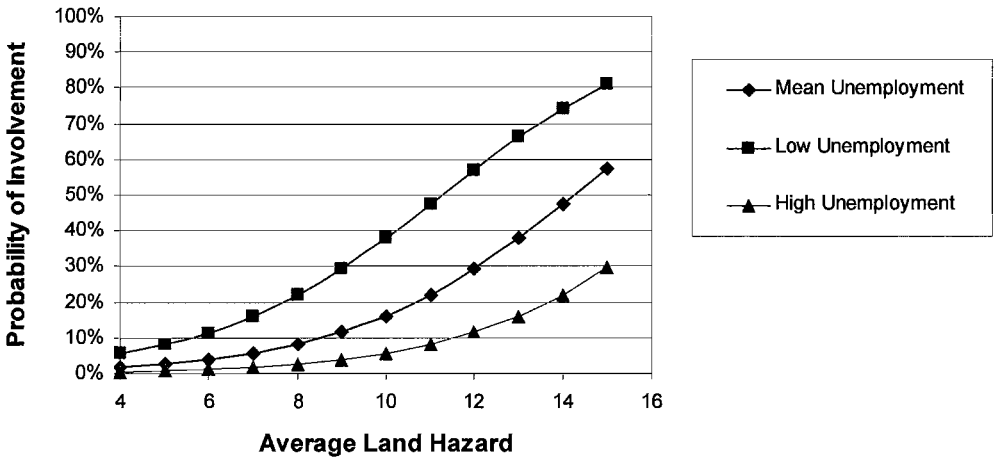
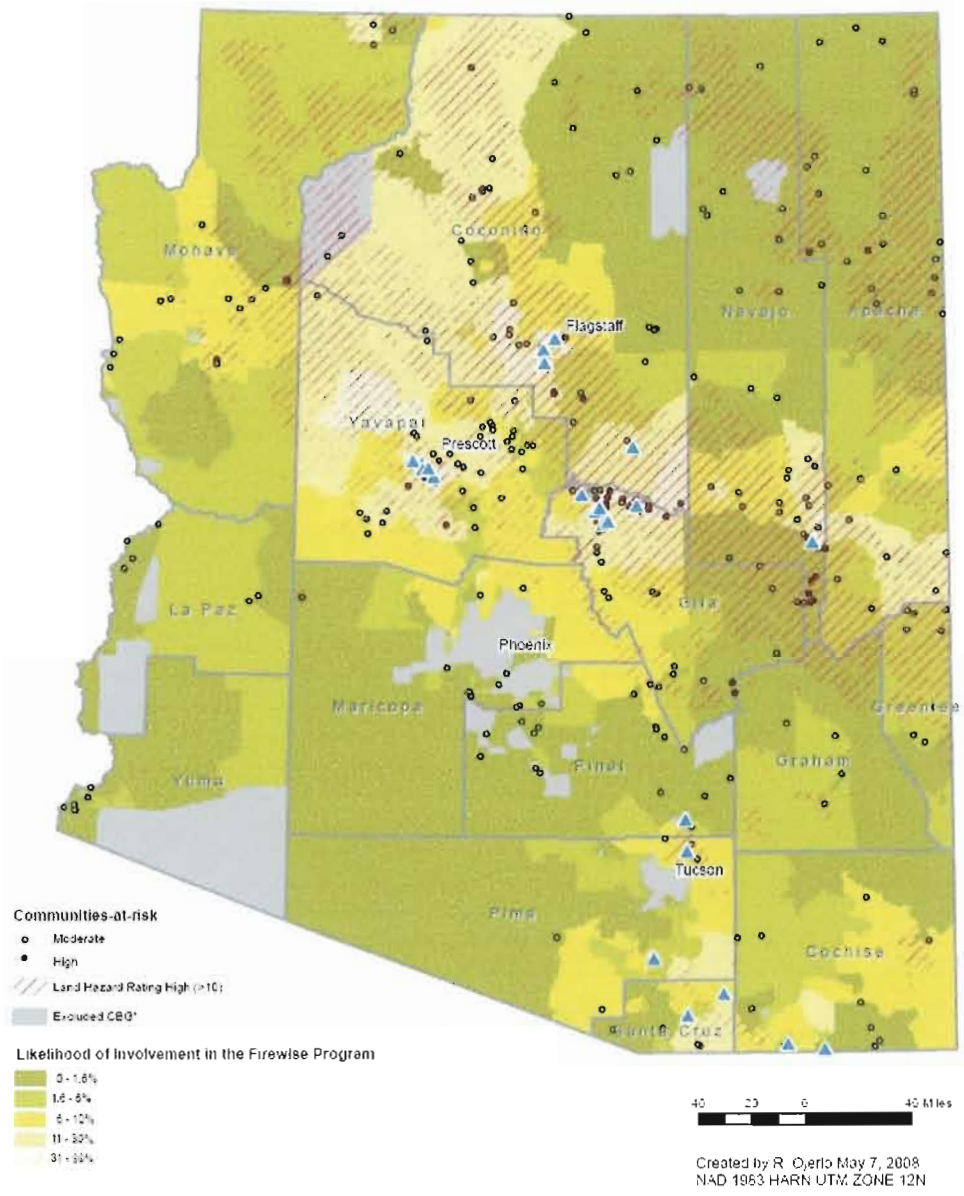


Figure 17. Probability of Involvement in the Firewise Program as a Function of the Average Land Hazard Rating and Percent Unemployment.



Using the statistical model with each biophysical and socioeconomic variable in the analysis (Model 1, Table 11), I calculated the predicted likelihood of involvement in the Firewise program for each CBG in the State. Map 3 illustrates the distribution of communities that have participated in the Firewise program along with these findings. Most of the Firewise communities are clustered around Flagstaff, Prescott and the northern portion of Gila County – areas that are generally more affluent and have a greater percentage of white residents that elsewhere in the state. Similar to the findings with CWPP and SFA grant involvement, the northeastern portion of the state and the southern tip of Navaho County have areas of both high fire risk and low predicted likelihood of involvement in the Firewise program.

Map 3. Firewise Recognized Communities and Likelihood of Involvement by Census Block Group.



* Excluded Census Block Groups where Census data is incomplete or the max. land hazard rating is very low (<4)

4.5 Summary

Collectively, the findings for each of the three outcome variables, involvement in the Firewise program, CWPP plans, and SFA grant funded projects, demonstrate that these wildfire mitigation activities are focused on areas of high biophysical risk to wildfire. The land hazard rating is positively correlated with each activity and the predictive effect is significant in every statistical model irrespective of socioeconomic characteristics. The structural density variable is also positively correlated with involvement with CWPP's and SFA grant projects but not Firewise involvement, though the correlation is less than that of the land hazard rating.

In terms of social vulnerability, those populations that are typically disadvantaged and marginalized are less likely to be involved in these wildfire mitigation activities. Regardless of which measure of social vulnerability is used from the suite of indicators included in this research, there is a significant disparity between the likelihood of involvement and level of socioeconomic status. The disparity is greatest in the Firewise program, but evident in all three outcome variables. For each of the three wildfire mitigation activities, the percent non-white residents is the most consistent and substantial predictor of involvement. Communities in Arizona with a high percentage of non-white residents are primarily Native American Communities living on Tribal Lands.

CHAPTER V

DISCUSSION

As competition for federal resources to mitigate wildfire risk becomes increasingly acute, it is all the more important to allocate those resources efficiently and equitably. The delivery of resources to communities-at-risk to wildfire should be strategic, providing assistance where it will result in the greatest marginal improvement in disaster resilience. The equitable approach would seek to equalize the burden of risk across individuals and communities. Disaster research shows that communities with low socioeconomic status bear a disproportionately large risk burden given the same biophysical risk factors as a more affluent community. Thus the concept of social vulnerability is an important factor in wildfire risk management.

The results of this study demonstrate that in Arizona, biophysical wildfire risk factors are significant predictors of community involvement in wildfire mitigation activities. However, the findings also demonstrate that traditionally disadvantaged and marginalized segments of the population are less likely to be involved in mitigation efforts throughout the state. Identifying these at-risk populations and understanding the underlying mechanisms that create the disparity is an important issue for planners, policy makers, community leaders, residents and others interested in the equitable and efficient use of federal resources.

Incorporating social vulnerability indicators in wildfire planning is a pressing issue because of the magnitude of the threat, but also because of the approach to risk management currently promoted by federal policy. That policy emphasizes proactive measures to reduce risk and empower communities to engage in wildfire planning and implementation. Despite efforts to provide resources, tools and technical assistance, this study demonstrates that socially vulnerable communities are less likely to be involved in wildfire mitigation efforts.

5.1 Prioritizing Socially Vulnerable Populations

This study used nine measures of social vulnerability based upon a review of the literature on natural disasters and wildfires. Results indicate that many of those measures were consistent and substantial predictors of involvement in federal wildfire mitigation program efforts – in general, socially vulnerable populations were less likely to be involved in wildfire mitigation efforts. Based on this finding, wildfire managers should use socioeconomic indicators to identify and prioritize socially vulnerable populations in an effort to increase the level of involvement in these communities. But which indicators should be used? Poverty, race, education, language and employment status were significant predictors across each of the mitigation activities. One possibility would be to use an index of each measure, but since these measures are also correlated with one another, selecting a single measure from the suite would likely be as effective and more efficient. As a practical matter, using poverty has advantages including precedence as an

eligibility criterion in other government programs and availability of data. Poverty is also more socially acceptable than race and language as eligibility criteria.

A social vulnerability measure, such as poverty, could be integrated into wildfire protection programs and plans in a variety of ways. First, poverty could be included in the comprehensive wildfire risk assessments along with the biophysical factors such as weather, forest fuels and topography to identify priority areas for fuels reduction work. The same risk assessment could be used to identify socially vulnerable communities and include goals in the CWPP to focus efforts on reducing structural vulnerability in those communities. At a larger scale, the Arizona State Lands Dept. Forestry Division could target socially vulnerable communities within the state and strive to assist those areas in developing CWPP's, pursuing grant applications for wildfire reduction activities and participating in the Firewise Communities USA program. At a national level, if these finders transfer to other contexts, the federal government should use poverty as an indicator of social vulnerability to identify regions where at-risk communities need additional assistance.

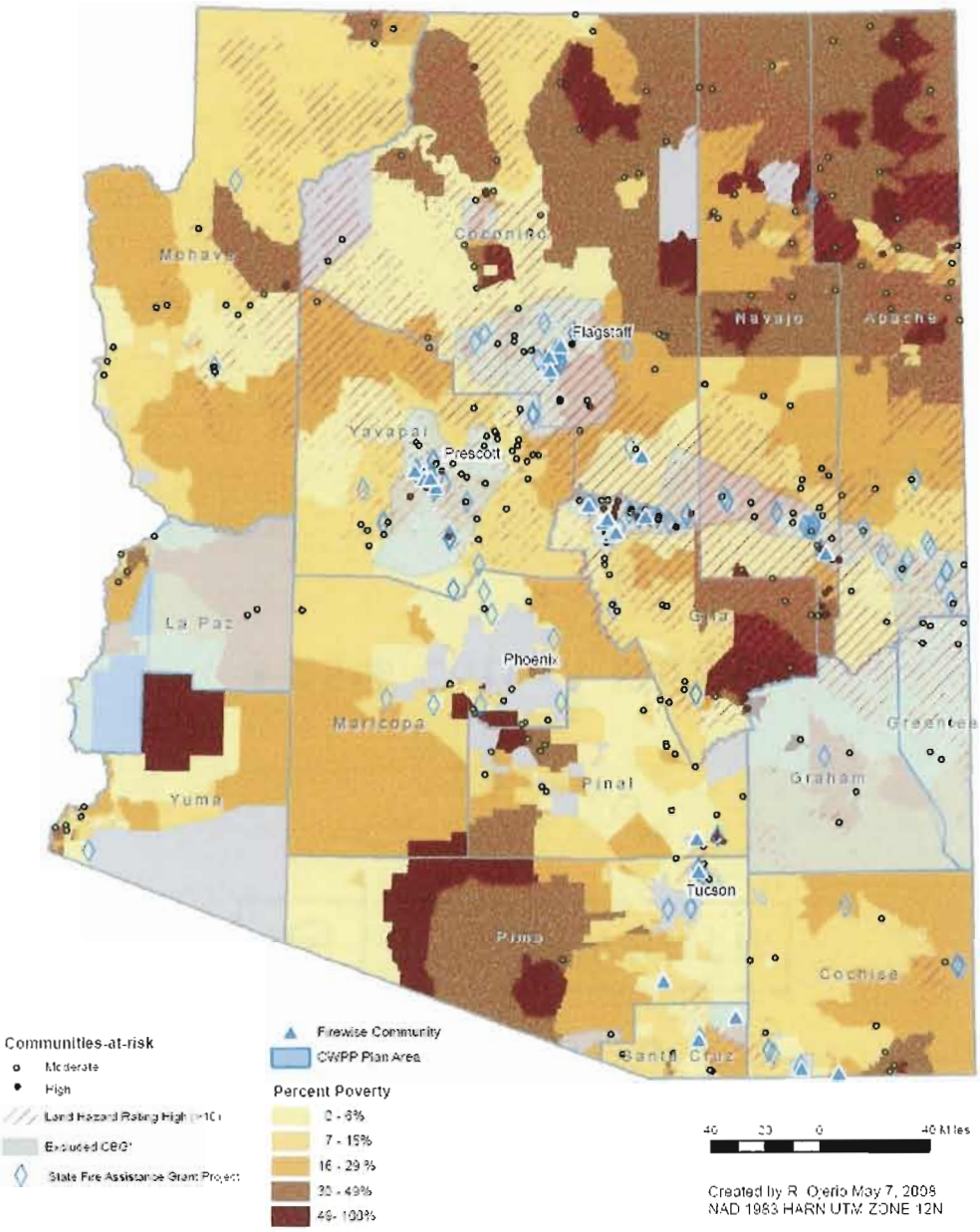
Similarly, a social vulnerability criterion, such as poverty, could be included in the State Fire Assistance (SFA) grant application to help to focus resources on these at-risk communities or the 50:50 match requirement could be lowered if it proves to be a barrier to participation from socially vulnerable communities.

Of the three wildfire mitigation activities, integrating a measure of social vulnerability into the Firewise program would probably be the most difficult to achieve since the participation in the program is initiated by the community. Without knowing

why socially vulnerable communities in Arizona are less likely to get involved it is difficult to prescribe effective solutions.

Map 4 illustrates the distribution of different wildfire mitigation activities, the percent poverty by Census Block Group, and areas with a high land hazard rating. High poverty communities that are also at high risk to wildfire are located in the northeastern corner of the state in Apache and Navajo Counties, the eastern portion of Gila County, and a few areas in the northern portion of Coconino County. This map highlights those areas were additional research could help explain why socially vulnerable communities are less likely to be involved in federal program efforts to reduce wildfire risk.

Map 4. Wildfire Mitigation Activities and Percent Poverty by Census Block Group.



* Excluded Census Block Groups where Census data is incomplete or the max. land hazard rating is very low (<4)

5.2 Next Steps

Additional research is needed to replicate the methods from this study in other states to see if similar disparities exist in other contexts. These studies should be paired with qualitative research to identify underlying causes and solutions. It would be particularly useful to conduct case studies of socially vulnerable communities that are involved in wildfire mitigation efforts and disseminate those findings amongst socially vulnerable communities and wildfire management practitioners.

With regard to participation in the Firewise program, I suspect that dispersed settlement patterns in rural areas are less conducive to the type of community organizing and grass roots projects that the program is geared towards; this could explain some of the findings from this study. Native American communities and other traditionally marginalized populations may also be less inclined to participate in government sponsored programs.

If further study indicates that a lack of awareness about the Firewise program is an issue, the Arizona State Lands Dept. Forestry Division, which coordinates the program, could target outreach efforts to socially vulnerable communities. Another barrier to participation in the Firewise program might be the requirement that the community demonstrates an annual expenditure of $2 per capita on wildfire mitigation activities. If so, financial assistance or a waiver of the requirement could help these communities get involved in the program and perhaps over time build their capacity to meet all the requirements.

5.2.1 Involving Socially Vulnerable Communities in Planning and Implementation

Additional research to clarify the causes and the solutions to the lack of social equity in wildfire management will take time. Including residents and representatives from socially vulnerable communities in the CWPP process could improve current wildfire planning and implementation. It is important to involve vulnerable populations and those who understand their needs in developing strategies that are appropriate and relevant (Rhodes and Reinholtd, 1998). The singular focus on vulnerabilities, however, overlooks potential capacities within populations that emergency managers could capitalize on to develop disaster resilience (Buckle *et al.*, 2000).

I suspect that social capital and effective community leadership is a critical ingredient to mobilizing human resources in so called "low-capacity" communities. I also am interested in the role that intermediaries play in engaging communities in these efforts. Public lands managers, researchers, emergency management staff and others involved in wildfire mitigation have an opportunity to build social bonds that bridge boundaries of race, class, organizational affiliation and political persuasion. I suspect that these relationships encourage the trust and reciprocity necessary for local actors to capitalize on outside resources. Furthermore, these bonds lead to more effective wildfire response and recovery (Carroll *et al.*, 2005).

Although natural resource managers, foresters, and forest fuels specialists are well trained in delivering technical solutions such as thinning fuels, community involvement requires experience and expertise in education, outreach, and social mobilization (Brooks *et al.*, 2006). Wildfire management practitioners may be building that experience, but a

continued effort is needed. Towards that end, state and local agencies need support and resources from the federal government to continue to promote effective community involvement in wildfire mitigation efforts.

5.2.2 Community Capacity

The concept of community capacity is another avenue of research that should be pursued. Researchers from many disciplines including public health, economic development, natural resource conservation and disaster management have explored the concept of community capacity. Typically, the concept is composed of several dimensions that describe a community's assets and abilities such as social, cultural, political and economic capital. Although there is little consensus on a precise definition of the concept, in the most general sense community capacity is the ability to respond to challenges and effect change that captures opportunities and fulfills the needs of community members (Donoghue and Sturtevant, 2007). In the wildfire context, community capacity can be defined as the ability of a community to organize and mobilize resources to prepare for, respond to and recover from wildfire (Evans *et al.*, 2007).

Despite much interest in the topic, previous research on community capacity has focused on clarifying definitions, but there has been little work to validate potential measures against specific outcomes and incorporate valid measures into planning and program evaluation (Donoghue and Sturtevant, 2007). The lack of tools to evaluate community capacity to engage in wildfire mitigation activities can hamper project goals

especially if those goals were drafted prior to learning about community's capacity and history (Brooks *et al.*, 2006).

Although this study did not directly evaluate community capacity, the finding that socioeconomic status is a predictor of involvement in wildfire mitigation activities suggests a relationship between these factors and community capacity. However, socioeconomic measures that represent levels of physical and human capital don't necessarily correlate with the community capacity for management and decision making (Buckland and Rahman, 1999), nor the quality of social networks and leadership which comprise social capital. For example, regional community assessment efforts during the 1990's that incorporated measures of socioeconomic status and social capital found positive correlations with community capacity. But high socioeconomic status did not always predict high social capital and some communities rated highly in social capital despite low scores on socioeconomic status (Donoghue and Sturtevant, 2007).

In short, community capacity is a complex topic deserving of additional research to clarify linkages between socioeconomics, social capital and capacity. The biophysical factors and dynamics of wildfire are also complex, yet CWPP's consistently include a comprehensive wildfire risk assessment of these variables. Similarly, planners should prioritize assessments of social factors to identify and support community deficiencies and build upon community assets and strengths.

In summary, findings from this research and other efforts to investigate social vulnerability in a wildfire context support the following recommendations:

- Use indicators of social vulnerability in comprehensive wildfire risk assessments;

- Modify grant criteria to reduce match requirements for poor communities;
- Prioritize grants and technical assistance for socially vulnerable communities;
- Research and disseminate findings from case studies where socially vulnerable communities successfully participate in wildfire mitigation activities; and
- Ensure that socially vulnerable populations are included in CWPP planning and implementation.

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