

Climate, Forest Fires, and Recreation: Insights from the U.S. Southwest

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Abstract

Forests rank among the foremost recreational destinations, no more so than in warm semi-arid bioregions. The US Southwest is no exception. Yet, while these areas provide respite from heat and sun, forest fire can pose a serious hazard to recreationists and nearby residents. In the US Southwest this hazard is elevated due to high fuel load buildups resulting from long-term fire suppression policies and to climatic influences. Tree-ring research provides strong evidence that wildfires in the region are linked to synoptic climate processes, notably the El Niño-Southern Oscillation (ENSO). The tree-ring archive for the past 500 years indicates that an unusually wet year, followed by one or two dry years is a particularly influential pattern: high winter precipitation in the first year encourages growth of fine fuels such as brush and grasses, while the following dry years cause the vegetation to become very dry, thus establishing widespread fire hazard conditions. At the same time, dry years are typically characterized by a greater number of sunny days, which may prompt increased visitation. US land managers address the multiple stresses affecting the region's forests through implementation of long-range plans that include both natural and human factors. An important element of these plans is management/reduction of fuel loads, largely focusing on prescribed burning. Shorter-term planning, focusing on the coming wildfire season, is also carried out each year. Knowledge of climate history and processes, and use of climate forecasts, could improve planning, although such information is not yet well integrated into these processes. Further, the plans do not yet deal with the potential implications of diffusion of climate information to the public, even though such information has considerable potential to influence tourism marketing and thus levels/patterns of recreational activity. Today, marketing of tourism in the forests of the US Southwest occurs at all scales from the global to the local, and income from tourism and recreation has become essential to many nearby communities. Increased understanding of climate and its impacts, as well as the implications of enhanced use of climate information by tourists, recreationists, marketers, and business people could enhance planning and decision making with regard to overall land management, fire management, and visitor management. This paper examines important intersections among climate, tourism/recreation and fire regimes in the Southwest, and suggests areas where our regional experience might contribute to similar climate-forest-recreation assessments elsewhere.

Keywords: Forest fire, Climate impacts, Recreation, US Southwest

Introduction

Recreation in the natural areas of the United States is a highly valued activity, one that is important to large proportions of the public. At the same time, many of the areas most valued by recreational users are located in areas where fire is a natural component in ecological processes. In 2000 alone, there were 92,250 fire starts and 7,393,493 acres (2,992,147 hectares) burned.

Management of wildland areas is complicated by a century of fire suppression practices that have rendered large tracts of forest and grassland highly vulnerable to catastrophic wildfire. Almost 40 million acres (16,188,000 hectares) of National Forest Service lands alone are deemed to be at high risk of wildfire. Wildfires are imposing substantial damage on both human and natural systems; at the same time the cost of fighting wildfires, as well as damage costs, are escalating (Husari, 2000). In the National Park system, policies that favor allowing lightning-ignited fires to burn while at the same time refraining from any active intervention to otherwise reduce fuel-load build ups have also resulted in high risk of catastrophic wildfire, as occurred in Yellowstone National Park in 1988 (see, e.g., Bonnicksen 1989).

Dendrochronological records for the U.S. West indicate that large-scale regional wildfires are correlated with sequences of wet and dry winter climatic conditions associated with certain climate patterns. Lag times between climatic conditions and fire occurrence indicate that periods characterized by one or more unusually wet winters, followed by one or more unusually dry winters, provide an entry point for predicting years when probabilities are high for worse than usual fire seasons (Grissino-Mayer and Swetnam 2000; Swetnam and Betancourt 1998, 1999, 2000). Yet adoption of new knowledge and information technologies designed to improve the use of fire-climate information and forecasts, and to improve understanding of links between climate and fire, has not yet occurred to any substantial extent. The following discussion places outdoor recreation in the context of climate and wildfire, and suggests that climate information can be useful not only for fire managers, but also for communities, businesses, and individuals who benefit from recreation and tourism activities but at the same time may be vulnerable to the impacts of fire-climate interactions. The paper concludes with recommendations for improving the resilience and adaptive capacity of

land managers, communities and recreationists located in or near fire-prone recreation areas in the US Southwest.

Background

Numerous publications reflect assessments of potential impacts of climate variability and change at scales ranging from global to local (see, e.g., IPCC 1990, 1998; USGCRP 2001a; USGCRP 2001b). Climate impacts on forest fire, and on tourism and recreation, are among the many issues addressed in these assessments. As noted in the most recent assessment for the United States, “forest growth is likely to increase in many regions, at least over the next several decades . . . [and] some forests are likely to become more susceptible to fire and pests” (USGCRP 2001a, p. 11). Given that forests cover nearly one-third of the U.S. land base, concern about climate impacts on fire regimes is well warranted, for climate influences composition, structure and function of forest ecosystems. Climate also affects the amount and quality of forest resources, as well as social values associated with forests and forested landscapes. Globally, the primary determinants of woody plant distributions are the spatial and temporal distribution of water and temperature (see USGCRP 2001a, p. 494). In assessing wildfire risk, relative humidity and fuel moisture levels are crucial. About 790 million acres (319,713,000 hectares) of federal lands in the United States are used for recreation; 95 percent of these lands are located in the West. In addition, state and local governments manage more than 54 million acres (21,853,800 hectares), of which 45 percent are in the West. (USGCRP 2001a, p. 508).

According to the U.S. National Assessment, outdoor recreation is likely to change as a result of seasonal climate changes, along with related changes in air and water temperatures (USGCRP 2001a, p. 510). However, because recreation is so broad in diverse with regard to its environmental requirements (Cordell et al. 1999), assessing the types, magnitudes, and patterns of change in recreational activity in response to climate change is difficult (USGCRP 2001a). At the same time, the National Assessment Report suggests that “Recreation is likely to expand in mountainous areas where warmer temperatures attract more people to higher elevations” (USGCRP 2001a, p. 510). Recognizing that alterations in disturbances in fire, drought, insect and disease regimes,

the report speculates that managers could attempt to cope with impacts in several ways: “influencing forest ecosystems prior to disturbance [through, e.g., changing forest density], mitigating the forest disturbance itself [e.g., through burning restrictions and prescribed fires to reduce fuel loads], manipulating the forest after the disturbance [e.g., through imposing fire, insect, and disease controls], or facilitating the recovery process [e.g., intervening to manage the system immediately after disturbance or throughout the recovery process through reseedling and other such activities]” (USGCRP 2001a, p. 511).

The National Assessment Synthesis Report (USGCRP 2001a) emphasizes that considerable research remains to be done on climate-forest ecosystem interactions, how land use practices and changes in those practices interact with climate variability and change, the interactions among multiple stressors on sensitivity and vulnerability to climate impacts, and human adaptation practices and capacities. As work in the southwestern United States has demonstrated, processes operating over multiple decades, or at the century scale, can affect the degree and nature of fire hazard. Global and synoptic-scale climate processes are correlated with regional patterns of wildfire activity (USGCRP 2001b).

Translating such knowledge and research into policy and decision making processes poses significant challenges. As indicated in a report by the National Research Council (1999) on the opportunities for and barriers to use of climate forecasts, our ability to model ocean-atmosphere interactions, and thereby predict seasonal to interannual climatic variations, has improved, particularly in the past decade. Yet seasonal and longer-term climate forecasts remain under-utilized. In the United States, successful predictions of the 1997-98 El Niño resulted in greater public awareness of climate forecasting. At the same time, much remains unknown about how awareness and use of climate information and forecasts affect decision making and behavior. Given that climate forecasts are inherently uncertain, knowing how to communicate uncertainty effectively is essential to building bridges to users of such information. This, in turn, requires improved understanding of patterns of sensitivity and vulnerability of natural and social systems to climatic stress, in order to determine what information people need, when they need it, and for what purposes (NRC 1999a). It also requires new and better

techniques for assessing the relative impact of climate among the multiple stressors that frame decision making and behavior in any given context (see, e.g., NRC 1999b).

Outdoor Recreation in The United States

Assessment of outdoor recreation in the United States requires a basic understanding of land tenure patterns across the nation. Most important is the fact that, particularly in the Southwest, much of the land is in federal or state ownership. Arizona is an extreme example of this: only 16 percent of the state's land base is in private hands. In New Mexico, less than half the land is in private ownership (see Figure 1 and Table 1).

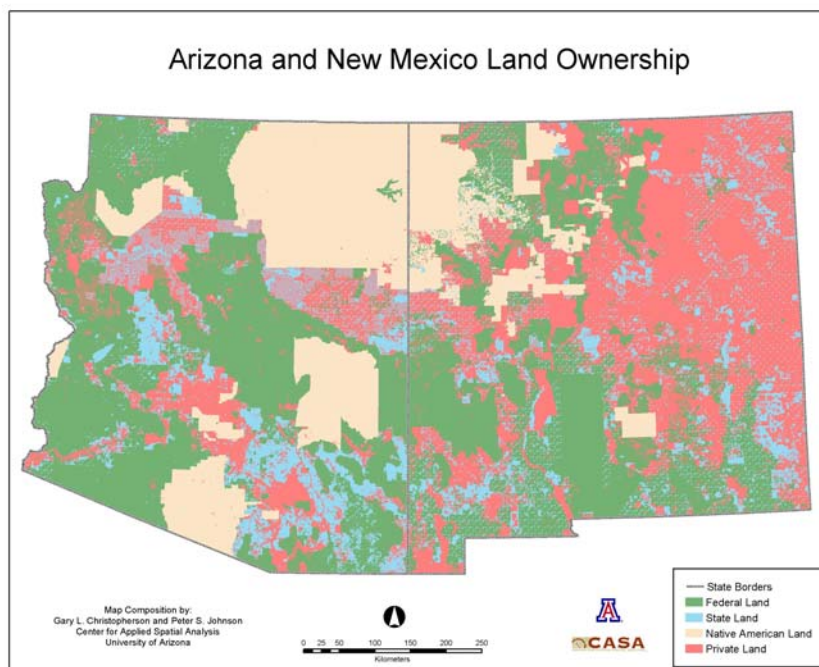


Fig. 1 Much of the land in the US states of Arizona and New Mexico is publicly owned (source: Center for Applied Spatial Analysis, The University of Arizona).

Table 1 Land ownership patterns in two southwestern states and total for the U.S. (source: Merideth, 2001).

Ownership Category	Percentage of Land		
	Arizona	New Mexico	United States
Federal government	44	36	31
State government	13	11	9
Native Nations	27	10	2
Private	16	43	58

Federal lands include those controlled by the U.S. Forest Service (USFS), U.S Fish and Wildlife Service (USFWS), Bureau of Land Management (BLM), National Park Service (NPS), and Department of Defense (Figure 2). The Forest Service alone manages 63 percent of the officially designated wilderness areas in the United States (USFS 2000). Recreational activities occur on at least some of the lands of all of the lands managed by federal agencies; however, obtaining sufficient data about levels and types of recreational activity is often difficult or impossible. This is particularly the case with regard to USFS and BLM lands, since no broadly implemented and maintained mechanism exists to regularly document and archive visitation statistics. What data exist for these and other areas comes from various surveys, which may only be conducted sporadically, and may involve use of non-compatible techniques. One survey, however, is regularly conducted and provides some insight into outdoor recreation at the national and broadly regional level. This is the National Survey on Recreation and the Environment, which has been conducted by the USFS since 1960.

The results of the survey conducted in 1994-95, which included 17,000 Americans age 16 and older, indicates that almost 95 percent of the population participates in at least one form of outdoor recreation (Cordell et al 1997). Outdoor recreation in the United States encompasses a very large number of activities, ranging from taking a casual walk to hunting fishing, camping and mountain climbing. Indicators of the activities listed in the survey that may be most likely to occur in forests and other natural areas, and changing trends in participation in these activities, are provided in Table 2.

Table 2 US Population Engaged in Selected Outdoor Activities (source: Cordell et al. 1997).

Activity	Number of U.S. Participants	% Change between 1982-1983 and 1994-1995
Hiking	47.8 million	93.5
Camping-developed areas	41.5 million	38.3
Camping-primitive areas	28 million	58.2
Bird watching	54 million	155.2
Back packing	15.2 million	73
Adventure activities (mountain climbing, caving, orienteering, rock climbing)	36.8 million	not available

Of the activities listed in Tables 2, hiking and primitive area camping have increased considerably in recent years. In many parts of the country, particularly the U.S. West, the kinds of outdoor activities listed above have high potential of occurring in areas of fire risk. While the number and proportion of Americans who participate in outdoor recreation provides some basic insights into how widespread such activity is, knowing something about the mean number of days spent in various recreational pursuits provides some clues about the intensity of use of recreational areas. As can be seen in Table 3, people living in the interior West and Pacific Coast, both areas where fire hazard can be especially high, spend more of their time in outdoor recreation than the average American does.

Table 3 Population Engaged in Selected Outdoor Activities – U.S. and Western U.S. (source: Cordell et al. 1997).

Activity	National		Interior West		Pacific Coast	
	Mean days	Number millions	Mean days	Number millions	Mean days	Number millions
Hiking	16.8	804.7	17.7	87.8	17.7	192.8
Camping-developed	10.7	442.4	9.8	39.3	10.6	92.9
Camping-primitive	9.2	258.6	9.6	34.6	10.3	57.5
Bird watching	87.8	4749.2	92.2	381.7	74.6	548.0
Wildlife viewing	36.9	2307.9	35.9	197.2	30.8	290.5
Back packing	8.6	129.7	8.2	14.5	9.6	36.4
Mountain climbing	4.4	39.8	6.5	9.5	5.2	11.2

Camping is a particularly interesting activity for assessing use of wildlands and for obtaining insights into potential vulnerability to wildfire events. Results of the Outdoor Recreation survey (Cordell et al. 1997) show that camping is somewhat more popular in the West than in other parts of the nation (34 to 38 percent of the population engage in camping as compared with 23-24 percent in the other regions), although the actual number of days people stay out camping is similar across the country, and across types of camping activities. Americans tend to camp, on average, 10 to 11 days a year in developed areas, and 8 to 10 days a year in primitive areas. The likelihood of camping tends to decline with increasing age, although camping with a recreational vehicle is similar for all age groups. This reinforces intuitive ideas that backcountry risk is borne primarily by younger people, while assessing the risks in more developed camping areas must take into account the likely presence of older people and families who may require special assistance in the event of emergencies such as evacuation due to wildfire threat. Fully 25 percent of the people in the interior West enjoy primitive camping, compared with 10 percent in the North and South (Cordell et al 1997). These individuals may be more difficult to identify and evacuate, in the event of wildfire hazard, particularly if they are camping in areas that do not require issuance of permits.

Outdoor adventure activities constitute other activities that may place people at some risk from wildfire. Such activities are enjoyed by about half the people in the West, in contrast to only about a third of the people in the North and South. Of the activities aggregated under this category in the most recent Outdoor Recreation Survey (Cordell et al 1997), off-road driving and horseback riding were most popular, with off-road driving more popular in the North and horseback riding along the Pacific Coast. Hiking is popular across all regions and age groups, with people even over age 50 being well represented. In terms of demographics, it is notable that some 8.3 million hikers and 1.6 million backpackers interviewed were older than age 50, a factor that may be important in situations where rapid evacuation may be required. Hiking is done on average 16-18 days per year in all regions of the United States. More people engage in hiking in the West than in the rest of the United States, and it is likely that much of the hiking occurs during fire season. Rock climbing, mountain climbing, orienteering, and caving, which

may also be linked evacuation risk, are also more popular in the West than elsewhere in the country (Cordell et al. 1997).

Fire Risk and Outdoor Recreation

In the western United States, the activities described above are likely to occur in areas and seasons of high fire risk. Although the record to date shows no significant links between wildfire events and death or injury among recreationists, the data suggest that a substantial proportion of the population may be at risk at any given time during the fire season. This, in turn, suggests a need for carefully focused research into the patterns, seasonality, and locations different types of recreational activity in fire-sensitive areas, demographics of the populations engaging in these activities, and perceptions of risk. The research should also assess the perceptions of land managers and fire managers regarding the level of risk faced by people engaging in recreation on the lands they manage. Camping, in particular, may pose high fire risk, not only for the campers themselves, but with regard to the risk for wildfires originating from improperly managed campfires.

Issues associated with management of wildlife, habitat, and ecosystems are inextricably intertwined with expectations, values, opinions, and activities of the public, as well as of land managers, policy makers, and researchers. Recreation-related economic activities ranging from construction to services and tax revenues, are also important in decision making regarding wildland and fire management. The Outdoor Recreation Survey (Cordell et al. 1997) revealed that the quality of the scenery in recreation areas was “very” or “extremely” important to more than 75 percent of survey respondents. The safety and security of the recreation area generated high levels of response as well, ranging from 73 percent in the West to 84 percent in the South (Cordell et al. 1997). While these responses refer to a wide variety of places, including for example urban swimming pools, picnic areas, etc., it is not unreasonable to assume that safety from natural hazards is also important for a large proportion of visitors.

In response to a question about whether management is well balanced between use and protection of recreational areas, more than half of all those surveyed agreed that this was the case. On the other hand, 26.1 percent of those along the Pacific Coast and 21

percent of those in the rest of the West disagreed, suggesting the significant extent to which how best to manage of western lands remains a contested issue. Even more revealing are the responses to the statement, “government should allow more private development on public lands.” Here, 45 percent of respondents in the North disagreed, as did 44 percent in the South. Significantly, fully 53 percent of those in the Pacific Coast region and 55 percent of those in the rest of the West disagreed. These opinions are important, for they contradict actual trends, which show continued expansion into wildlands, as well as expansion of the urban-wildland interface, another factor that must be considered in the context of wildfire risk.

As discussed below, fire is a part of the natural process in the western United States, but at the same time may pose substantial risks to both visitors and residents. These risks exist in a complex context of growing outdoor recreation activity, increasing pressure on natural resources, expansion of human habitation ever farther into wildland areas, significant contests involving traditional resource-dependent activities such as ranching and logging and environmental advocates, fluctuating levels of resources for management of recreational lands and resources, and relative level of economic dependence on recreation and tourism.

Wildfire and Recreation in the U.S. West

The U.S. West is internationally known for its scenic beauty and the wide array of recreational opportunities available. In recent decades, the West has become a magnet for population growth (see Figure 2) and economic development in no small part because of the available recreational amenities. Tourism dollars are a significant source of income in the region and may be crucial to the vitality of some communities, particularly those located in or near major recreation and tourism

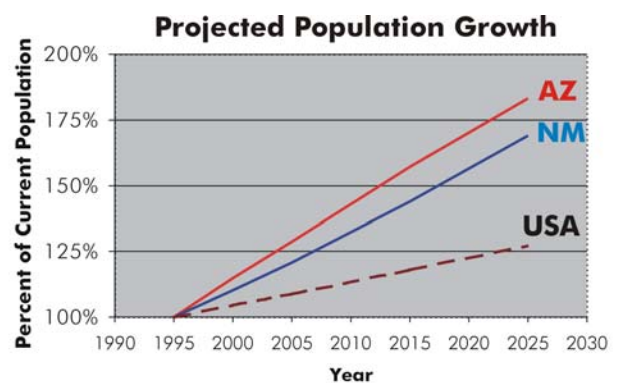


Fig. 2 Arizona and New Mexico are expected to continue growing at a much more rapid rate than the US as a whole (source: US Census and CLIMAS 2000).

destination areas. For example, according to one estimate, tourism accounts for \$12 billion in the economy of Arizona; it generates 115,000 jobs and supports an additional 185,000 indirect jobs (Arizona Department of Commerce, 2001). In rural communities, dependence on recreation and tourism income can be particularly high. Many of these same areas are areas of high wildfire risk, due to a combination of factors: fire-adapted ecosystems, increasing human encroachment on wildland areas, and a century of fire suppression that has resulted in development of exceptionally high fuel loads. Added to these factors, the region is characterized by a high degree of climate variability, both temporally and spatially (Sheppard et al. 1999).

According to forest managers, residents within the southwestern region account for much of the recreational activity in the region. This reinforces research findings indicating that people in the United States now tend to spend shorter amounts of time and to travel shorter distances engage in recreational activities (Cordell et al. 1997). Knowing patterns of wildland visitation, including points of origin as well as destination, activity, and length of stay, can be valuable sources of insight into the extent and nature of fire risk. Such information may also provide insights into the extent and nature of humanly caused wildland fire, as well as the interactions between human behavior, fuel condition, and climatic conditions.

While data analyses for the southwestern states of Arizona and New Mexico are not currently available, data for California provide insights into the value of recreation in the United States, particularly in the U.S. West. These data indicate that the annual average value of recreation in the state is \$1.5 billion. The impacts of wildfire on recreation values are estimated to range from \$5 per average acre burned on BLM lands to \$107 per average acre burned on lands in the state park system. In areas that are scenic, visible or publicly accessible burn, the value is estimated to be much higher (Forest Products Laboratory 2001). Based on US Forest Service data, wildland recreation in California has been estimated in recent years to average 112.1 million recreation visitor days per year (a recreation visitor day (RVD) is defined as 12 hours of participation in any recreation activity). The estimated average market value of this recreation is \$13.26 per RVD (Forest Products Laboratory 2001). Added to this are

values associated with housing units existing in the urban-wildland interface (discussed later in this paper).

In the U.S. West and South, the widespread fires of summer 2000 produced exceptional losses. Contextualizing the season in terms of local impacts brings home the severity of the season. In remarks to the U.S. Senate Energy and Natural Resources Committee, Subcommittee on Forests and Public Lands Management (September 23, 2000), for example, Idaho Governor Dirk Kempthorne catalogued some of the impacts of fire in his state: 86,000 tons of smoke related pollution were released statewide; tourism fell by 60 percent because of the fires. A total of 1.2 million acres (485,640 hectares) burned in the state, consuming enough timber to build 100,000 single-family homes. In Montana, as a result of the 307,000-acre (124,243-hectare) fire that burned in the Bitterroot Mountains in the summer of 2000, businesses reported a loss of \$270 million; Montana recreation outfitters alone lost \$36 million in canceled trips. A total of 240 structures, including 70 homes, were lost in that fire (Grandstaff 2001).

Climate in the US Southwest

In order to examine potential linkages among climate, wildfire, and outdoor recreation in

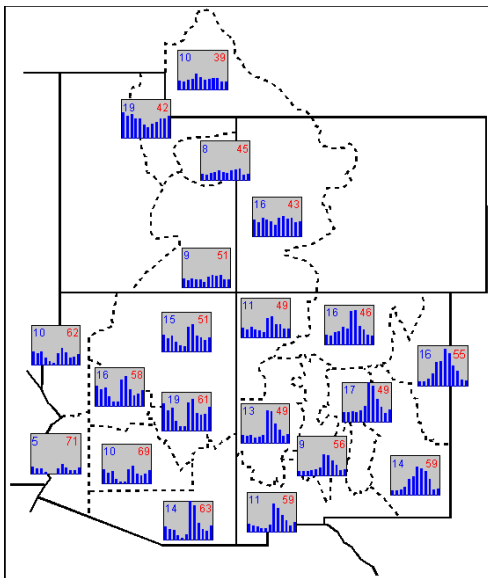


Fig. 3 Precipitation by Month, Colorado River Basin (source: Sheppard et al. 1999).

the southwestern United States, it is first necessary to have a basic understanding about the region's climate. At the annual timescale, the climate of the Southwestern United States (see Figure 3) is characterized by a bimodal regime, with precipitation concentrated in winter and summer months (see Sheppard et al. 1999 for a summary of scientific knowledge about climate in the region). The region lies at the interface between the subtropical and mid-latitude climate regimes. It is dominated by the North American monsoon, with related convective storm activity in the summer, and frontal activity in the winter. Precipitation may

also occur during the fall due to tropical storm activity. Spring, by contrast, tends to be quite dry. Summer rainfall tends to be highly localized, depending on storm cell location and intensity of convection. Microbursts occurring over a few kilometers are not uncommon. By contrast, winter precipitation tends to be broader in geographical extent and longer lasting in terms of duration, though less intense. While summer precipitation typically is greater in volume, winter precipitation is more important with regard to contributions to streamflow, groundwater discharge, as well as to overall moisture levels that influence levels of fire hazard.

The climate of the Southwest is characterized by a high degree of spatial and temporal variability (Sheppard et al. 1999). This variability is associated with the area's high variation in topographic relief (see Figure 4), its



Fig. 4 Topographic Relief, US Southwest

location (with regard to atmospheric circulation) in the interface between the subtropical

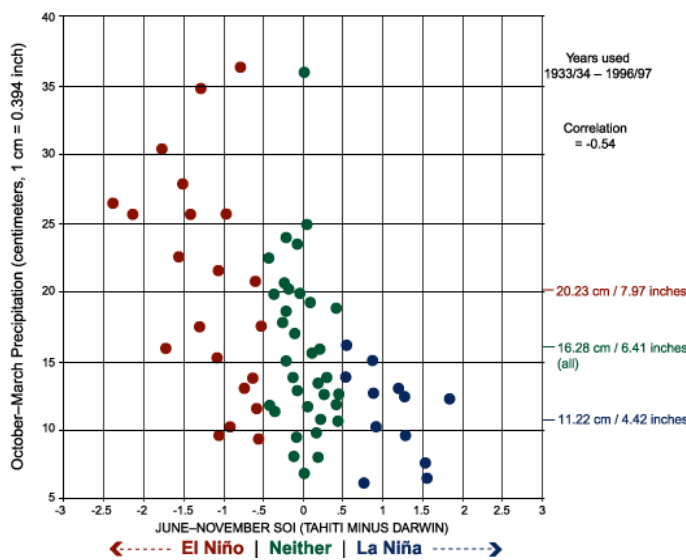


Fig. 5 ENSO Impact Patterns on Precipitation in the US Southwest (source: T. Pagano, 2001).

and midlatitude climate regimes, and the influence of synoptic-scale climate processes.

Lowland desert areas tend to receive much less precipitation than do high-elevation areas. Temporal variation in the quantity and quality of snowpack is also important, since both the depth and water equivalence of the snow influence fuel

moisture levels over the typically dry spring months. Viewed from a regional scale, these months constitute the height of season in the Southwest. Viewed from the perspective of interannual timescales, winter climatic variability in the Southwest is influenced by El Niño-Southern Oscillation (ENSO), with El Niños tending, on average, to produce higher than normal winter precipitation and lower temperatures and La Niñas tending even more strongly to produce drier than normal conditions (see Figure 5).

Dendrochronological research, based on tree-ring archives for the past 500 years, shows that large, regionally extensive fire years correlate to particular patterns of wet/dry climate patterns (Grissino-Mayer and Swetnam 2000, Swetnam and Betancourt 1990, 1998, 1999). As illustrated in Figure 7, ENSO conditions correspond to many significant

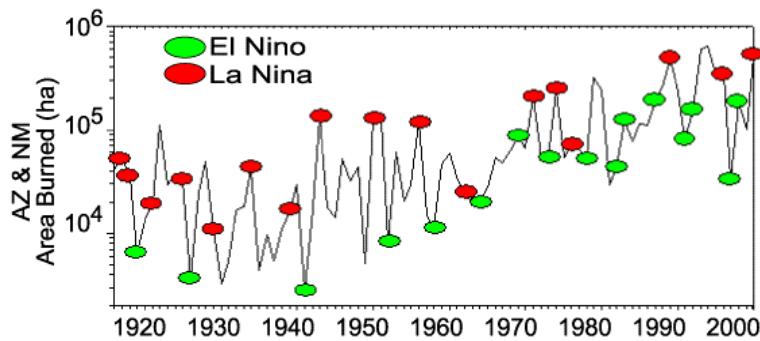


Fig. 6 Relationship Between ENSO and Fire Occurrence: Arizona and New Mexico, 1920 – 2000 (source: T. Swetnam, 2001).

fire years. Of particular note, multi-year climate sequences consisting of one or a few abnormally wet years, followed directly by one or more very dry years, correlate with particularly large regional wildfires.

Recent patterns bear these findings out: the very wet El Niño winter of 1997-1998 was followed by the very dry La Niña winters of 1998-1999 and 1999-2000. A recent analysis found that, at the scale of the entire U.S. West, no significant statistical correlation existed between the relatively weak La Niña conditions during winter 1999-2000 and the 2000 fire season. Rather, the analysts suggested that perhaps anomalously warm tropospheric temperatures may have been implicated. They did note, however, that while the links between the 1999-2000 La Niña did not hold for the entire West, the strongest correlations were found between the two occurred in the Southwest (Brown and Hall 2001).

Whether or not ENSO was a significant influence on the 2001 wildfire season, dry conditions generated by longer-term climatic patterns were certainly implicated in the

intensity and extent of wildfire activity. Specifically, dry conditions persisted throughout the winter; these conditions were followed by a very dry summer. The combination assured that fuel moisture levels would be exceedingly low, setting preconditions for widespread fire hazard. Many of the largest fires occurred in areas that had already been affected by extended drought conditions.

Recent advances in our ability to use ENSO measurements to forecast winter climate a year or more in advance, are allowing us to improve our capacity to predict relative changes wildfire risk at least a season in advance. Forecasting skill for non-ENSO winters, and for summer-season precipitation, remains extremely low in the Southwest. However, even in non-ENSO years, recent forecasts based on statistical approaches or ensemble analysis of multiple forecasts produced from an array of experimental and operational forecast sources are proving useful in predicting areas of greater and lesser wildfire risk at coarse scales of resolution.

Another climate regime affecting the U.S. Southwest, the Pacific Decadal Oscillation (PDO), appears to enhance the ENSO signal and thus may also influence wildfire regimes. In this case, the positive phase of the PDO may strengthen El Niños (generating a greater potential for wetter than normal El Niño winters) while the negative phase may strengthen dry conditions in La Niña winters (Sheppard et al 1999). These conditions, by influencing vegetation growth and fuel moisture levels, may enhance or reduce chances for large wildfire events, though considerable research and longer-term monitoring is required to affirm linkages between PDO and wildfire in the region.

In general, however, in the Southwest, the PDO tends to strengthen or weaken the ENSO signal, depending on whether the two are in phase or out of phase. There is some evidence that we have experienced a shift in PDO regime in the past few years to the negative signal, which could result in overall decadal or longer drier conditions in the Southwest, thus possibly weakening El Niño (wet) and strengthening La Niña (dry) impacts. The last time the Southwest experienced this phase of the PDO was in the 1950s, when decadal-scale drought conditions plagued the region (Swetnam and Betancourt 1998). As indicated in Figure 7, this was also a time of significant die-off of trees. Tree regeneration did not occur until the 1980s, which coincides with a positive

(stronger El Niño) phase of the PDO. Scientific corroboration of the connection between PDO patterns and tree die-off and regeneration remains to be made, however.

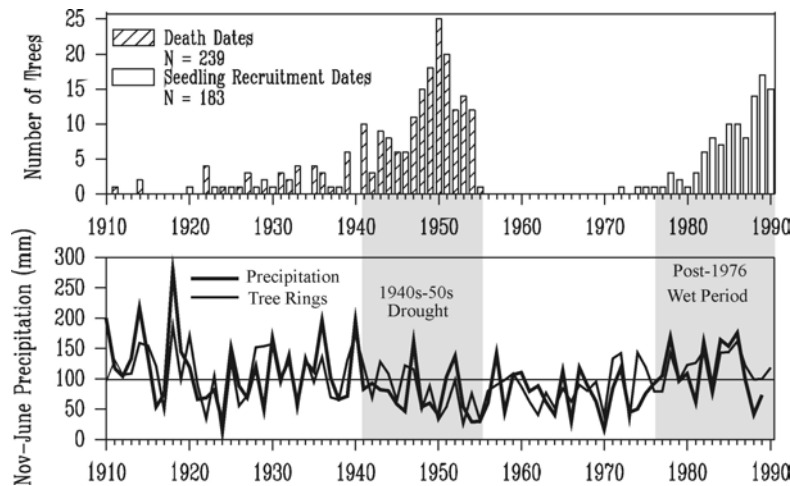


Fig. 7 Tree Death and Recruitment Relative to Extended Drought and Wet Periods 1910 – 1990 (source: J. Betancourt and T. Swetnam, unpublished).

Climate and Fire in the Context of Recreation in the U.S. Southwest

Recreation and tourism are very important to the economies and lifestyles of residents of the Southwest, and the many scenic areas provide abundant vacation opportunities for people from the U.S. and from abroad. National Park Service data for 1998, for example, show 12.8 million visits to NPS units in the region, with 11.6 visits occurring in Arizona and 2.1 million in New Mexico (which has fewer national park lands) (Merideth, 2001) (see Table 1).

In the Southwest, most of the wildland recreational activity occurs on public lands. The large extent of public (largely federal) ownership of lands in the region has significant implications for managing tourism in the context of climate and wildfire, for each land management agency has its own rules and policies, even though they all cooperate in fire management through an inter-agency organization, the National Interagency Fire Center (NIFC).

The National Park Service, within the U.S. Department of the Interior (DOI), has a longstanding practice of minimizing interference in natural processes. By contrast, the Bureau of Land Management, also within DOI, actively manages most of its lands for

maximum forage production (the agency also manages some wilderness and protected areas where less-intrusive management is practiced) and for other “multiple use” objectives. The Forest Service, within the U.S. Department of Agriculture (USDA) and the second-largest U.S. land management agency (BLM is the largest in terms of land managed), has found itself increasingly managing its lands for recreational uses, as opposed to earlier emphases on resource extraction activities such as timber production, livestock grazing, and mineral exploration. Like the other agencies, the USFS also has wilderness and other protected areas that it manages with minimal intrusion. Fire suppression, until the past couple of decades, has been the predominant policy with regard to fire management for all non-wilderness areas. While this policy has resulted in the kind of dense forests beloved by many recreational users, it has also created conditions of high fire danger.

All of the agencies distribute leaflets about wildfire hazard and many provide other interpretive information about the benefits and dangers of fire at visitor centers and headquarters. Written policies are also in place requiring posting of information about fire danger and prescribed fire activity. The web sites for the national forest units may provide short-term weather forecasts and average climate information as well. However, there is very little information available to the public that correlates climatic conditions and trends with actual or potential fire danger. For organizations and firms specializing in recreation and tourism at scales from the global to the local, as well as for individuals, such information has potential to beneficially influence planning and decision making within this sector. Likewise, for emergency personnel, climate information may assist in efforts to plan for potential need to take extra steps to protect recreational visitors. This is no small responsibility, as exemplified by a 1996 fire in the Grand Canyon area, when ten hikers had to be airlifted out of the Canyon by helicopter, a dangerous operation even in the best of times. In that same time period and area, 21 firefighters were sent to the hospital, and two neighborhoods in Flagstaff, Arizona were evacuated (CNN 1996).

The Urban-Wildland Interface and the Southwest

The urban-wildland interface constitutes a growing issue throughout much of the country, but especially in U.S. West and Southwest, due to an increasing desire to locate

residential and commercial structures located in or near fire-prone wildland areas . Ewert (1993) has catalogued a variety of definitions for the term: (a) two traditional land uses that occur near or adjacent to each other (Bradley 1984); (b) an area of interaction between different political forces and potentially competing interests (Vaux 1982); (c) a residential/wildland interface that represents areas where problems are related to the urban environment (Lee 1984); (d) a natural resource ‘ecotone’ where a transition occurs between two communities comprising urban and natural environments and containing characteristics of both; the zone has unique attributes as well (Hansen 1962). Ewert stresses that important differences exist between interface areas and more remote locations, based on functionality. The urban-wildland interface, he maintains, provides an array functions, including outdoor recreation, watershed services (water quality and quantity), improvement in air quality, commodity production, reduced stormwater runoff peak flows, close-by wildlife habitat, and space for urban and industrial development. These areas also provide restorative environments (see Kaplan and Caplan 1989).

The interface has also been broadly defined as “the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels” (National Wildland/Urban Interface Fire Program, no date, <http://www.firewise.org/>). Forested areas have especially high value for residential development, both for year-round and recreational use (see Figure 8 for an illustration of growth patterns near national forests in the U.S. western states). Property values may be significantly enhanced in a forested setting, yet closely spaced trees, picturesque roofs with wood shingles, perimeter areas filled with pine needles, a large woodpile close to the house, and other elements actually increase fire hazard considerably. A program initiated through a collaboration of the U.S. Forest Service, National Association of Foresters, U.S. Bureau of Land Management and Bureau of Indian Affairs, National Park Service, US Fish and Wildlife Service and National Fire Protection Association seeks to educate residents in interface areas about how to protect their properties and lives from devastating wildfire, and how to work together to minimize the risk (see <http://www.firewise.org/> communities). The program was established in the wake of devastating wildland fires and loss of more than 1400 homes in California and Florida in 1985.

However, this program has not yet incorporated climate considerations into its risk evaluation and mitigation process.

Data assembled for California provide some basic insights into the magnitude of potential risk fire risk at the urban-wildland interface. According to 1995 data from the California Department of Forestry and Fire Protection, 35 percent of the state is considered to be in the urban-wildland interface zone; 25 percent of the state's population is estimated to live in this zone. Another report notes that there are an estimated 1 million housing units in wildlands or in the interface zone in California. The estimated replacement

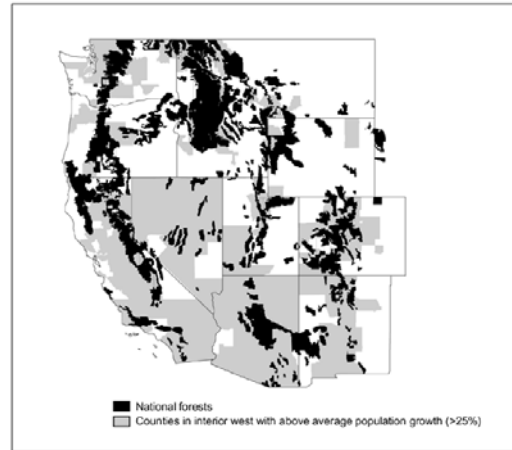


Fig. 8 County-Level Population Growth >25% and Location of National Forests (source: US Government Accounting Office, 1999).

values of these homes is \$107 billion for the structures alone. Fire records for the time period 1985 – 1994 indicate that some 703 homes are lost each year to wildfire in the state. The average loss per home burned (including value of contents and other tangibles and intangibles) amounts to some \$232,000. The average total annual monetary loss associated with loss of homes to wildfire in the state is \$163 million. According to the Insurance Services Office, Property Claims Services, between 1970 and 1993, there were \$3.5 billion in inflation-adjusted losses occurring from catastrophic wildfires.

Data for Arizona indicate that 129,680 homes are at risk from wildfire. The number of household members at risk has been estimated at 341,058, and the projected value of loss from these homes burning at \$10,387,368 (Polley and Thal 2001). The nature of the interface varies widely in the Southwest. Flagstaff, for example, a scenic and rapidly growing city in northern Arizona, is situated on a large, high-elevation plateau in the midst of mixed conifer landscape. The city has 40,000 acres (16,188 hectares) in the urban wildland interface. By contrast, Tucson, Arizona, located at the base of three mountain ranges in the Sonoran desert in the southern part of the state, has approximately 34,000 acres (13,760 hectares) of wildlands are in the urban interface zone

(<http://www.fs.fed.us/r3/coronado/fire>). Here, the steep gradient from the desert floor to the highest peaks, approximately 2,500 feet above sea level to some 10,000 feet (4345 m to 3048 m) provides an environment in which fires may burn through vegetation ranging from cactus forests through chaparral, oak, pine and spruce-fir forests. This transition among vegetation types occurs within 27 miles (43.45 km), which is equivalent to the kinds of changes one normally sees when traveling from Mexico to Canada. The at-risk interface areas are located in the foothills adjoining the Santa Catalina, Rincon, and Santa Rita Mountains that lie, respectively, on the northern, eastern, and southern sides of the city. The fact that the wildlands are within full view of the city, where those watching the fire may voice strong demands for aggressive interventions that may, for example, put fire fighters at high risk adds to the challenges managers face in managing fires in this zone. Further, heavy use of the wildlands at the interface pose challenges for fire management. The Santa Catalina Mountains alone feature more than 1,100 miles of trails, a small lake, a ski resort, campgrounds, and picnic areas. A small permanent community, Summerhaven, is located on top of Mount Lemmon in the Catalinas. This community, which has a permanent population of about 100 and a seasonal population of about 300, is at especially high risk of destruction from wildfire and poses large problems for protection of residents in that it has only one paved escape route.

All of the mountain areas in the Tucson area, as well as in other urban-wildland interface areas of the state, receive heavy recreational use. Serious issues exist with regard to lack of sufficient evacuation routes in most of these areas. Further, while signs advise visitors of fire hazard, based on assessment of current weather conditions and related fuel moisture, there is no good information available about longer-term fire hazard based on assessment of climate impacts on fuels.

Fire managers on Coronado National Forest, in southeastern Arizona, regularly carry out prescribed burns, generally at a scale of 2,000 to 6,000 acres (809 to 2,428 hectares) per year, to decrease the risk of damaging wildfires. Even so, they anticipate an increase the number of management-ignited and non-suppressed, naturally occurring burns in the future. At the same time, with urban growth continuing in the interface zone, the imperative to reduce fire hazard continues to intensify. Whether thinning and prescribed burning can sufficiently reduce the risk of catastrophic losses from wildfire in

urban interface areas of the Southwest is an open, and intensely debated, question. Local fire ecology experts express serious doubts that wildfire events can be prevented, even with these measures, due to the exceptionally large amounts of fuels that need to be cleared out and a related lack of sufficient institutional and resource capacity to reduce hazard levels in any relatively short time frame. Equally challenging is convincing the public that open, park-like vistas are more desirable and valuable than the dense forests that most people are accustomed to enjoying.

The kinds of risks described above are increasing across the Southwest, including areas that have up until now been relatively remote from “urban” encroachment. For example, the Chiricahua Mountains, in southeastern Arizona, have traditionally been surrounded by rural uses, particularly ranching. But now, with aging of the ranching population and increased conversion of open spaces to alternative uses (especially primary and secondary residences), the nature of fire risk is changing, and interface-related fire risks are certain to escalate.

Even remote protected areas may present considerable risk. At Chiricahua National Monument, located about 3 hours’ drive southeast of Tucson, visitation averages around 85,000 people a year. Heaviest visitation occurs in the spring, the season when wildfire danger is highest due to the typically dry conditions that prevail April, May and June. Dry conditions over one or more preceding winters can produce increased fire risk during these months. The use of the canyon bottoms (which are full of hazardous fuels) for hiking, and the location of visitor facilities and residences of staff members in a box canyon that has only one outlet, pose potential challenges for staff who may have to evacuate themselves and visitors rapidly. The Monument’s wildfire management plan (NPS 1992) stipulates that areas can be closed if staff believe fire danger warrants such action, but does not explicitly link climate with assessment of fire danger. With increased conversion of surrounding ranchlands into seasonal and permanent residences, and with what is likely to be a related rise in recreational activities in the Monument and surrounding Chiricahua National Forest, recreation-related wildfire risk is sure to increase.

The story of the Cerro Grande Fire in Los Alamos, New Mexico illustrates many of the issues raised in this paper. This fire was set as a prescribed burn in May 2000 in a high-elevation forested area of Bandelier National Monument but escaped, eventually burning 43,000 acres (17,402 hectares). Costs and losses associated with the fire are estimated to exceed US\$1 billion. The fire destroyed more than 200 homes and other



Fig. 9 Popular Recreational Trail After Cerro Grande Fire, Los Alamos New Mexico, May 2000 (source: D. Honeyman).

structures. Some 18,000 people were evacuated from the communities of Los Alamos and White Rock. Residents came back to a severely altered landscape: many of their favorite hiking areas had been transformed from inviting forests and trails to moonscapes of charred remains. Subsequent reseeded and relatively wet winter conditions restored a green carpet to much of the area, but recreation options

have been altered radically (see Figure 9). Some areas remain off-limits entirely; others will not return to their forested state for fifty years or more (Ramos and Percy 2000, Foxx 2001).

The original prescribed burn was one of a series of fires that had been detailed earlier in the Monument's fire management plan. The decision to light the fire was based on an assessment that fuel moisture conditions in that particular area were conducive to setting a controllable fire (see NPS 2000). However, the assessment did not take into account essential information about the fuel conditions in nearby lower elevations, nor did it take into account climate information which indicated that (a) strong winds were typical at that time of year and (b) based on more than 500 years of fire history data, a wet year, followed by one or more dry years, were highly correlated with major wildfires (NPS 2000; see also, e.g., Swetnam, Allen and Betancourt 1999). This was very much the case, for a very wet 1997-98 El Niño was followed by dry winters in 1998-99 and 1999-2000.

Scientists speaking at a workshop, held in February 2000 to alert fire managers about exceptionally strong potential for widespread wildfire in the US Southeast, Southwest, Intermountain West, and Pacific Coast regions, had stressed that prescribed burns should not be set during the 2000 fire season, based on the pattern of climatic events and existing fuel load conditions. Although individuals who might have influenced the process that ultimately resulted in the Cerro Grande fire participated in the workshop, analysis of the post-fire assessment (NPS 2000) reveals that embedded knowledge and practices of decision makers prevailed over openness to incorporating alternative information. The workshop, one of a series subsequently organized by the Institute for the University of Arizona's Institute for the Study of Planet Earth (ISPE) and Laboratory for Tree-Ring Research (LTRR), specifically aimed to establish communications between fire managers and climatologists in order to "raise a red flag" that the probabilities were very high that it would be a bad fire year for much of the West, Southwest, and Southeast. The fire year turned out to be worse than anyone anticipated.

Introducing Climate Information into Strategic Wildfire Planning

Information is significantly lacking about how many visitors are in wildland areas of the Southwest at any given time. Even in areas where visitors must pay an entry fee or obtain a back country permit, long-term records of visitation patterns by month or by season may not be available in any usable form. This makes it very difficult to track climate influences on visitation patterns in terms of numbers of visitors, where they came from, where they are going, length of stay, and proposed activities. It also confounds efforts to incorporate recreational patterns and visitor data into climate-related fire risk assessments.

Nevertheless, climate impacts can be assessed in other ways, notably with regard to influence not only on fire regimes, but also on policy making and institutional change. Integrated assessment projects, such as the Climate Assessment for the Southwest (CLIMAS) project, funded by the Office of Global Programs of the U.S. National Oceanic and Atmospheric Administration (NOAA-OGP), afford a multidisciplinary approach to incorporating such issues into assessments of climate sensitivity, vulnerability, and adaptation capacity. Further, through providing Web-based information

and holding events such as fire-climate workshops (see, e.g., Garfin and Morehouse 2001), researchers associated with the University of Arizona (Tucson, Arizona) and the Desert Research Institute (Reno, Nevada) seek to build skills among fire managers, land managers, and other decision makers in interpreting and using climate information and climate forecasts (<http://www.ispe.arizona.edu/CLIMAS> and <http://www.dri.edu/CEFA>).

Three fire-climate workshops have been held to date, one in winter 2000, and two in the late winter of 2001. Each was supported by funds from the University of Arizona's Institute for the Study of Planet Earth, NOAA-OGP, and the U.S. Forest Service's Riverside Fire Laboratory; the two workshops held in late winter 2001 were also supported by funding from the Joint Fire Science Program of the National Interagency Fire Center. At the workshops, climatologists and fire researchers are encouraged to identify information needs, as well as the possibilities and caveats associated with using such information. Many of these discussions focus on the use and utility of climate forecasts as well as of historical and paleoclimate information and fuel load assessments. Spatial scales of the climate information provided range from global to local and temporal scales range from one month to seasonal, annual, and interannual. Among the primary goals of the workshops is providing information useful for improving strategic planning for prescribed burns and anticipating resource needs to fight wildfire before and during the fire season in each region. Tourism and recreation concerns need to be explicitly addressed in venues such as these, as well as in projects aimed at development of new decision support tools to be used for anticipating and planning for fire risk. As discussed below, this task has multiple facets and requires multiple research and information/knowledge transfer strategies.

Conclusions and Recommendations

In the aftermath of the Summer 2000 wildfires, the U.S. Congress appropriated \$1.8 billion for wildfire management. An initiative is underway to assure that some of this funding goes toward fire-climate research and improving the use of climate information in fire planning. One goal of such research should be identification of vulnerabilities and existing adaptation strategies associated with recreation and tourism in and near wildlands. Another should be development of a better understanding of the institutional

factors that either facilitate or constrain adoption of new knowledge and information by both resource managers and the recreation/tourism industries. Further, improvements are needed with regard to understanding in the public values, perceptions, and beliefs that influence decisions about recreation—including location, duration, and types of activity as well as any trends influencing values, perceptions, and beliefs. We also need to continue working on identifying the kinds of climate information needed to prepare for and respond to changes in wildfire hazard, as well as how best to disseminate the information effectively to the wide range of potential users of such information.

Climate forecasts have potential to furnish valuable input to fire planning processes, including planning for prescribed burns as well as for anticipating resource needs associated with seasonal wildfire projections. However, the potential benefits of climate information for fire management have not yet been fully assessed, largely because such forecasts have not yet been fully integrated into strategic planning processes and policies. Optimism exists that climate information will soon begin to play a role in planning and decision making processes. For example, the Joint Fire Science Program, an interagency initiative that (among other things) coordinates fire research and funds research projects, included climate climate-fire research and introduction of climate information into decision processes in recent calls for research proposals.

In the Southwest, such concerns, as well as other issues related to developing better scientific knowledge and better ways to visualize and communicate complex scientific information, are being addressed through a number of avenues, including development of experimental web-based information products aimed at both experts and non-experts, and development of proposals for funding of research projects designed to develop new scientific knowledge and improve our understanding of the structural and institutional factors facilitating or impeding the adoption and use of climate information and forecasts.

Such projects hold promise for improving communications among scientists, decision makers, and the public, including the many people who engage in recreation on fire-prone lands. University of Arizona researchers associated with WALTER (Wildland Alternatives project), for example, are currently working on a project funded by the U.S. Environmental Protection Agency, to build an integrated, GIS-based model for use in

strategic planning for fire management. The model, FCS-1, focuses on four specific mountain ranges, the Jemez Mountains in New Mexico and the Chiricahua, Huachuca, and Santa Catalina-Rincon Mountains in Arizona (see Figure 10). The model combines climate, fuels (see Figure 11), fire history, and social factors in a manner that will allow users to build scenarios through modifying parameters, and thus produce a map showing the spread of a hypothetical fire based on the scenario constructed. The intent is to construct a prototype that can be refined through further research and development and that can be modified for use in other geographical areas. While fully using the model will require considerable expertise to run, a simplified version is expected to be made available to non-experts, including community members in each of the study areas.

As noted above, the CLIMAS Project sponsors an annual fire-climate workshop for addressing common

research issues as well as presenting forecast information for the coming fire season. The project also proposes to add mesoscale analysis of climate-fire relationships in the Southwest within the next two years. The goal of this initiative is to develop information needed to improve regional fire-climate prediction and modeling capacity. In addition, research is currently underway to develop new techniques for building knowledge about the many institutional factors that may influence the integration of climate information and forecasts into decision making processes.

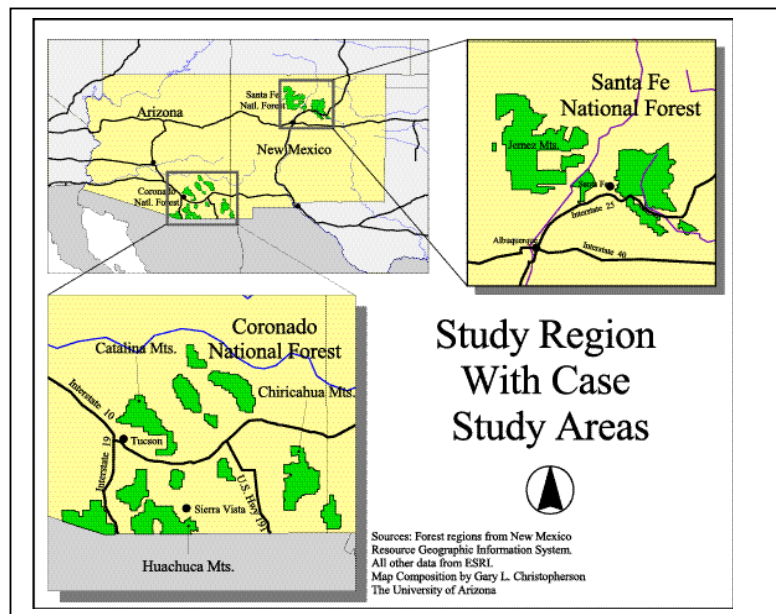


Fig. 10 The FCS-1 case study sites include three mountain ranges in southeastern Arizona, and one in northern New Mexico (source: Center for Applied Spatial Analysis, University of Arizona).

The impacts of climate variability and change on tourism and recreation remain seriously understudied; this is an area that clearly needs to be addressed. The need is very apparent with regard to the U.S. Southwest, where recreational activities and residential development are generating intensive impacts on wildlands and wildland interface areas. In this context, not only are climatic patterns of importance for protecting individuals, communities, and property, but human activities are crucial to the development of fire regimes in the context of climatic variability and change. Attaining the kinds of information needed to address these questions requires long-term research and monitoring. This in turn requires a much more focused effort on tracking recreational use patterns, as well as assessment of changes in cultural values, institutions, and policies.

Substantial links exist between recreation, forest fire, and climate in the southwestern United States. Yet knowledge of how the three factors interact to produce varying levels of risk not only in terms of fire hazard to recreational users, but also in



Fig. 11 Heavy Fuel Load Conditions in the Santa Catalina Mountains (source: B. Morehouse).

terms of economic impacts and community resilience and adaptation capacity. Further, fire itself, as well as the impacts of prevention and mitigation strategies (including the use of climate information), may have significant but as yet poorly understood impacts on social and cultural structures and values. Much research remains to be done to better understand these issues. Carrying out such research requires much better data than are currently available, particularly

at the level of individual public lands units. Such data needs to be collected regularly and in a methodologically consistent fashion, with the goal of building long-term time series. Both collection and archiving of these data need to be standardized in order to allow comparisons at local, regional, national, and international scales. The international component is important for developing comparative studies across the globe and is essential in regions, such as the U.S. Southwest, that are located along international

borders. Finally, communication of the data must be carried out in a fashion that emphasizes transparency; that is, the procedures used to collect the data, the means of archiving, any caveats related to the use of the data, and other such information must be readily available and understandable not only to scholarly researchers but also to those in the public and private sectors who seek to use the data.

Addressing the above requirements would facilitate not only research within particular localities, regions, or nations, but also comparisons across different geographical areas, climate regimes, and ecosystem types around the world. From the perspective of fire-climate-recreation/tourism research, investigations focusing on links among these elements in arid and semiarid lands is especially needed, particularly those which explore how to expand the range of information available for making decisions about where, when, and how long in advance to plan for utilization of fire-prone lands and resources. Such research should aim to integrate perspectives from a variety of natural-science and social-science disciplines as well as those of government agencies, communities and individuals whose missions, activities and livelihoods may be seriously affected by wildfire events. In addition, regular interactions among all of these entities should be supported. Such interactions would be very useful for sharing knowledge and experiences, identifying commonalities and differences among regions and social systems, and ultimately working toward development of common techniques and theories for assessing the implications of climate and wildfire for the very important areas of tourism and recreation.

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