Fire History and Climate in the Southwestern United States[1]

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Abstract—Forest fire occurrence during the past three centuries was examined using historic records from documents and fire-scarred trees. The influence of climate on fire regimes was apparent in regional synchroneity of large fires and association of reduced fire activity and El Niño-Southern Oscillation (ENSO) events. The latter association may have forecasting value.

In the study of centuries-long patterns of change in forest ecosystems one can observe recurrent themes, even "cycles," if we define this term in a nonclassical sense. For example, consider the well known successional pathway of aspen stands establishing after stand-replacing fires in mixed-conifer or spruce-fir forests. The aspen are, in turn, replaced by regenerated shade-tolerant conifers and, finally, recurrence of another fire storm may repeat the process. Management practices on public lands also seem to run in cycles. Consider the historical fact that fire suppression was essentially nonexistent in western forests before the first decade of this century. "Let burn" practices held sway in a number of areas in the 1910s and 20s, particularly California. The "hit-em hard and hit-em fast" strategy of the 10 AM policy finally won out completely in a heated controversy in the early 1930s, and the pendulum was then solidly on the total suppression side. In the 1970s and 80s land management agencies in the western U.S. shifted back toward the approach of using fire for management purposes. Although the term "let-burn" was still banned from the fire management lexicon, it was clear that the pendulum had moved back toward center.

Part of the cycling of fire policy may be linked to the cycling of fire regimes. Public (i.e., political) support of the early total suppression policy grew out of the shock of devastating fires in the late 1800s, such as the Hinckley and Peshtigo fires in the Lake States, and the 1910 fires of the Northern Rockies. Now, following the catastrophic fires in California and the Pacific Northwest last year, and the Yellowstone and other western fires this year, we are seeing a similar "fire shock" both in the public and land management agencies. Are we now poised for another shift in fire policy, presumably back toward the total suppression side? I think not, but any reassessment of policy has much to gain from a historical perspective. If we are to avoid further "fire shocks" we must recognize that regional-scale fire years have occurred in the past, sometimes despite aggressive total suppression policies, and these events will very likely recur in the future. Management strategies must be geared to minimizing these resource impacts through forecasting of hazardous conditions, fire–fighting readiness, and prudence in the use of prescribed fire.

The main theme of this paper is that historical and ecological knowledge can provide managers with perspectives necessary to meet these challenges. The focus is on historical records of fire and climate in Arizona and New Mexico during the last 300 years. Analyses of weather records also reveal that one particular climatic phenomena, the El Niño-Southern Oscillation (ENSO), seems to explain a substantial amount of the year-to-year fire load in the southwest. The ENSO-Southwestern fire teleconnection (Swetnam and Betancourt, in preparation) suggests that during some years it may be possible to forecast fire season severity several months in advance.

Methods

Historical fire records were compiled from two general sources: (1) Forest Service documents covering the post-1900 period, and (2) fire-scar records on trees covering the pre-1900 period. The Forest Service documents included data on number of fires and acres burned per year in the Southwestern Region (Arizona and New Mexico), USDA Forest Service. These data were analyzed by size class and totals. Sources were annual National Forest Fire Reports (USDA, Forest Service) and a detailed study of southwestern lightning fire data conducted by Barrows (1978). A longer record was compiled for the Gila National Forest in southwestern New Mexico from fire atlases and individual fire reports (Swetnam 1983a), and from an early fire statis-

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tics study by E. W. Loveridge in 1926 (files at Gila National Forest Supervisor's Office, Silver City, NM).

Pre-1900 fire occurrence data were compiled from fifteen fire-scar chronologies. These include 13 chronologies from Arizona and New Mexico, one from Mexico (Sierra Los Ajos, Sonora) and another from Texas (Guadalupe Mountains National Park) (fig. 1.). The fire-scar chronologies were developed by collecting full or partial cross section samples from living and dead fire-scarred trees, crossdating the annual rings (Stokes and Smiley 1968) and observing the position of fire scars within the annual rings (Dieterich and Swetnam 1984). Table 1 lists published and unpublished sources of the data sets and various other characteristics of the fire regimes.

Results

Post-1900 Fire History

A positive trend in number of fires reported each year was evident in the records of fire occurrence. Most of this effect was due to improvements in detection and fire-fighting resources available to send to fires. For example, in the Gila National Forest there were only 4 to 6 fire guards on horseback available for fire fighting from about 1909 to 1933, and the number of fires reported was relatively low during this period with no noticeable upward trend (fig. 2). Then in 1934 over 100 men of the Civilian Conservation Corps (CCC) were stationed within the National Forest and the fire record shows a obvious upward trend. Other detection and fire suppression improvements also correspond to increases in total numbers of reported fires (fig. 2). Most of this increase, however, was in the number of small fires (class A, 0.25 acres or less). It seems likely that in the first 20-year period the Gila fire guards

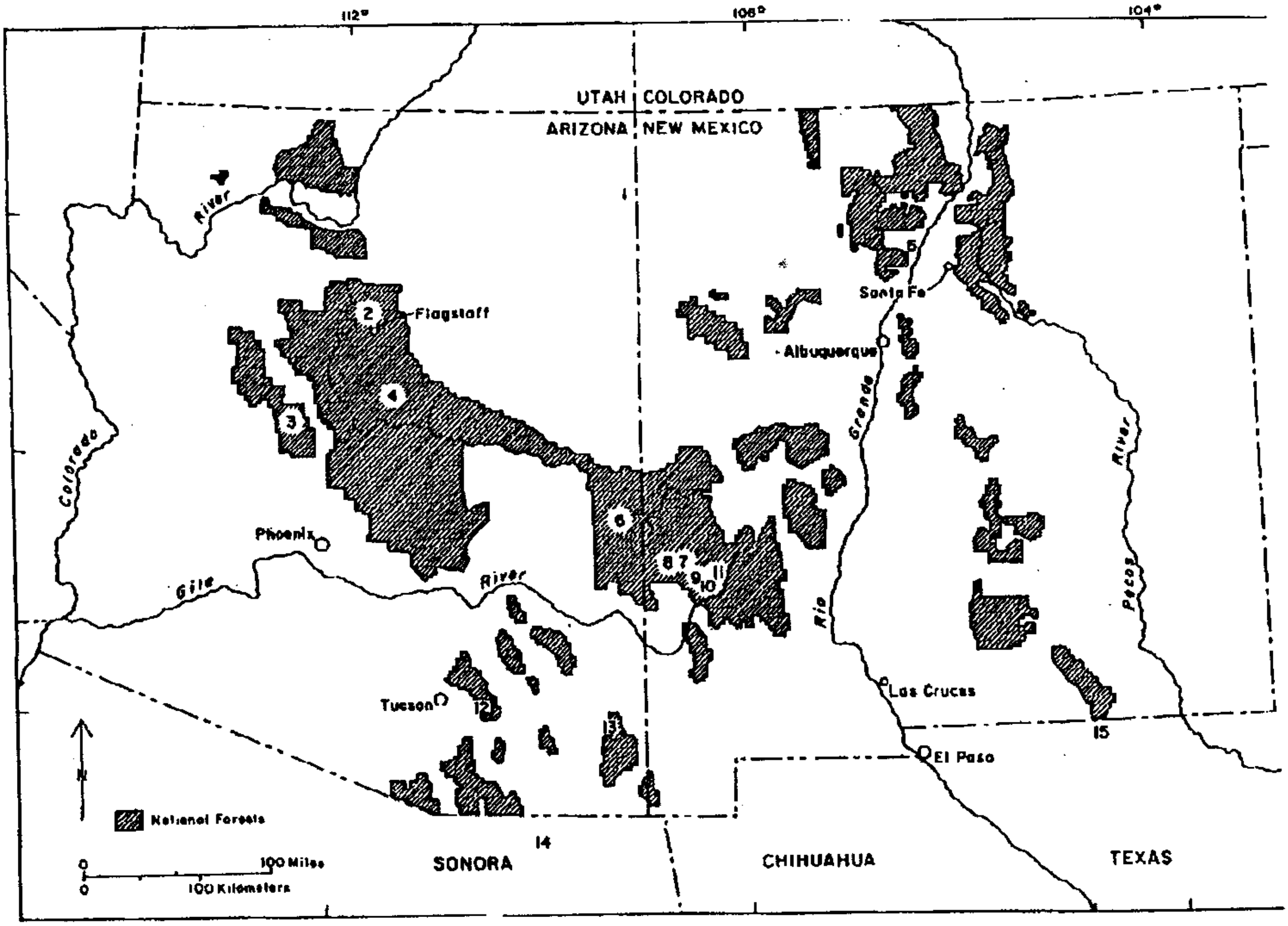

Figure 1.—National Forests in the Southwestern Region, U.S. Forest Service, Arizona and New Mexico. Fire scar collections are numbered and are described in table 1.

were probably unable to detect all fires that started, and even if they had they would not have been able to go to all of them.

Although improvements in detection and increase in manpower explain most of the increase in fire numbers in the Gila, there also appears to be more larger fires. The number of large fires reported in the Southwestern Region may also have a slightly upward trend (fig. 3). Table 2 compares the number of fires by size class for selected early and late periods in the Southwestern Region and the Gila. For the Southwestern Region, only the number of class A fires has significantly increased in the modern period; however, the number of fires in all size classes has increased in the Gila.

While improved detection and fire-fighting resources may account for the increase in number of small fires the increase in number of larger fires, may have a different explanation. Possibilities include change in climate and/or change in fuel loadings toward conditions favoring larger fires. Another possible contributing cause may be increased commercial and public use and access to National Forest lands, because there was also a statistically significant increase in average annual number of person-caused fires in the modern period (Gila record: 1909-1939, X = 12; 1960-1986, X = 18, t = 2.87, p = 0.006) (also see fig. 2). It is not known how much of the increase in large fires in the Gila was due to human ignitions because data on person-caused fires classified by size were not obtained.

Other evidence suggests that an increasing trend in fire load was not related to person–caused fires. Consider the lightning fire data for the Southwestern Region (table 3).

Barrows (1978) compiled the first 36 years of this record, and he also noted the steady rise in area burned per fire. He pointed out that the high area burned figure for the 1970s was strongly influenced by large fires in 1971 and 1974; 1979 was also an unusually heavy fire-load year.

One possible bias in the record after about 1974 was the increased area burned under prescribed natural fire programs, where lightning ignited fires were allowed to burn during special conditions. However, when the area burned under this program in the Gila Wilderness (which had the most active program well into the 1980s) was discounted from the 1970-1979 period, the average area burned per lightning-caused fire was still 6.66 ha, which was more than 40% greater than the previous 10-year period. The magnitude of the prescribed natural fire effect on area burned per fire for the 1980-1987 period has not yet been assessed because of lack of data. In any case, the rise in area burned per lightning-caused fire from 1940 to at least 1979 seems to be a genuine phenomenon that suggests a worsening fire situation in the Southwestern Region.

Obvious trends in total area burned per year were generally not observed (fig. 4). However, large peaks during certain years of this record are notable, reflecting especially severe fire years (e.g., 1925, 1946, 1951, 1956, 1959, 1960, 1971, 1974, 1979, and 1985). In some years, large burned area values can be traced to one or a few very large fires on a single National Forest, such as 1951 when two fires burned over 20,000 ha in the Gila. However, the majority of the peaks in fire activity in the Southwestern Region record represent regional-scale fire years

Table 1.—Fire-scar chronologies from southwestern United States. Periods of sample coverage between 1700 and 1900 were selected for comparsion of fire interval stst**i**stics among the sites. Fire intervals were periods in years between fire events that were recorded by more than 10% of sampled trees that were fire-scar susceptible at the time of each fire event. Numbers beside site names refer to figure 1.

Site	Name	Forest[1] type	Period	Fire intervals (years) Mean	S. Dev	Max.	Source[2]
1.	Chuska Mountains	P	1700-1895	5.0	5.2	24	1
2.	Chimney Spring	P	1754-1876	2.5	1.5	8	2
3.	Battle Flat	P	1750-1861	1.9	1.5	11	3
4.	Limestone Flats	P	1750-1998	2.9	2.0	10	4
5.	Frijoles Canyon	P-MC	1709-1899	7.3	5.1	23	5
6.	Thomas Creek	P-MC	1702-1893	9.8	6.9	26	6
7.	Gilita Ridge	P	1705-1899	4.9	3.1	18	7
8.	Bearwallow	MC	1705-1879	7.3	6.5	21	8
9.	Langstroth Mesa	P	1705-1892	5.1	3.8	22	7
10.	McKenna Park	P	1705-1890	4.5	2.8	12	7
11.	Black Mountain	P-MC	1702-1899	6.5	4.1	20	9
12.	Mica Mountain	P-MC	1703-1893	6.1	2.6	13	10
13.	Rhyolite Canyon	P-MC	1707-1886	8.5	5.5	21	11
14.	Sierra Ajos	P	1800-1899	4.5	2.1	11	12
15.	Guadalupe Mtns.	MC	1704-1879	8.8	6.9	26	13

[1] *Forest Type: P = Pure or nearly pure ponderosa pine forest: MC = mixed conifer forest. P-MC = Mixed conifer forest but with dominant component of ponderosa pine in some areas and other species such as Douglas-fir and white fir also present.*

[2] *Sources (unpublished reports and data sets on file at Laboratory of Tree-Ring Research, University of Arizona, Tucson, are indicated with *): 1. *Savage (1988); 2. Dieterich (1980a); 3. Dieterich and Hibbert (this volume); 4. Dieterich (1980b); 5. *Caprio et al. (1988) and Allen (1988); 6. Dieterich (1983); 7. Swetnam and Dieterich (1985); 8. *Baisan (1988b); 9. *Baisan (1988a); 10. *Baisan (1988b); 11. *Swetnam et al. (1988); 12. *Swetnam (1983); 13. Ahlstrand (1980).*

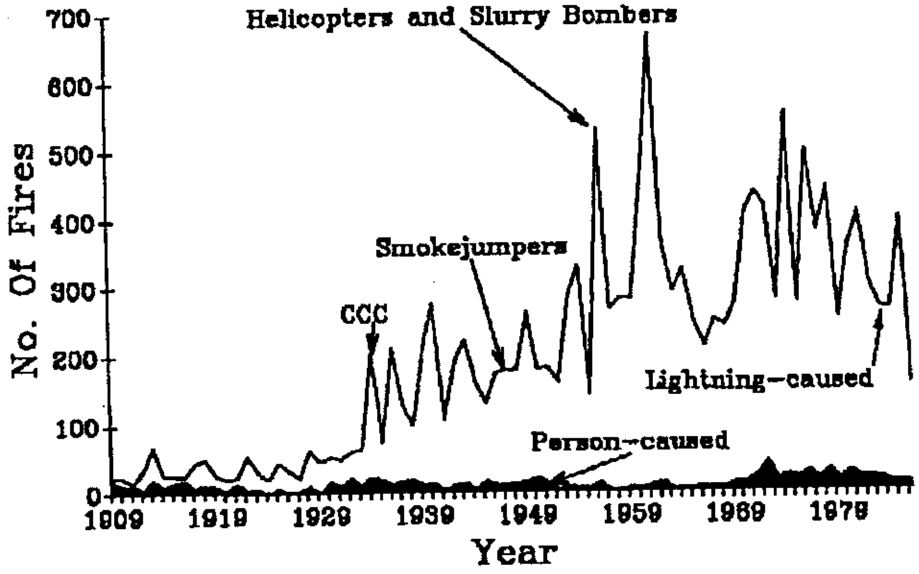

Figure 2.—Number of fires reported per year, 1909-1986, in the Gila National Forest, New Mexico. Approximate timing of improvements in fire-fighting technology correspond with increases in numbers of reported fires.

when large fires were reported in many of the National Forests.

Pre-1900 Fire History

Time series of the fifteen fire-scar chronologies listed in table 1 are illustrated in figure 5. This chart demonstrates the frequent and aperiodic nature of forest fires in ponderosa pine and mixed-conifer forests of the Southwestern Region during the two centuries before 1900. One of the most striking and consistent observations derived from nearly all of these histories was the sudden end of a surface fire regime in the late 1800s, or very soon after the turn of the century. Very few or no fire scars were recorded on any of the trees represented in figure 5 after 1900, with the exception of the chronology from Sierra Los Ajos. This chronology recorded a relatively uninterrupted regime of frequent surface fires extending into the 1980s when the trees were sampled. Recurring fires in the twentieth century at this site may reflect few or no attempts to suppress fires on this relatively remote mountaintop of northern Mexico.

Many fires during the presuppression era burned for months at a time, and they covered thousands of hectares. We know this must be true because lightning ignites fires in some ponderosa pine forests as early as April, with at least two months of dry conditions remaining. Some fires might have persisted through the rainy season of July and August and flared up again during drier periods of late summer and early fall. Also, fire scar records collected from numerous trees scattered over ponderosa pine forests as large as 2,000 ha show matching fire dates among most trees for most fires, indicating very large burns were typical in this type.

The mean fire intervals for all chronologies range between approximately 2 and 10 years (table 1). Mean fire intervals in ponderosa pine sites on the Mogollon Rim (central Arizona and west-central New Mexico) and southward range from 4 to 5 years, while mean fire intervals at higher elevations in mixed-conifer types range from 6 to 10 years. The mixed-conifer chronologies often recorded smaller fires at short intervals. When only larger fires in this type were considered, the mean fire intervals were on the order of 15 to 25 years (e.g., Dieterich 1983). Three of the northern Arizona chronologies (Limestone Flats, Chimney Spring and Battle Flat) recorded the highest fire frequencies of any forest type, with mean fire intervals ranging between 1.9 and 2.9 years. Consecutive-

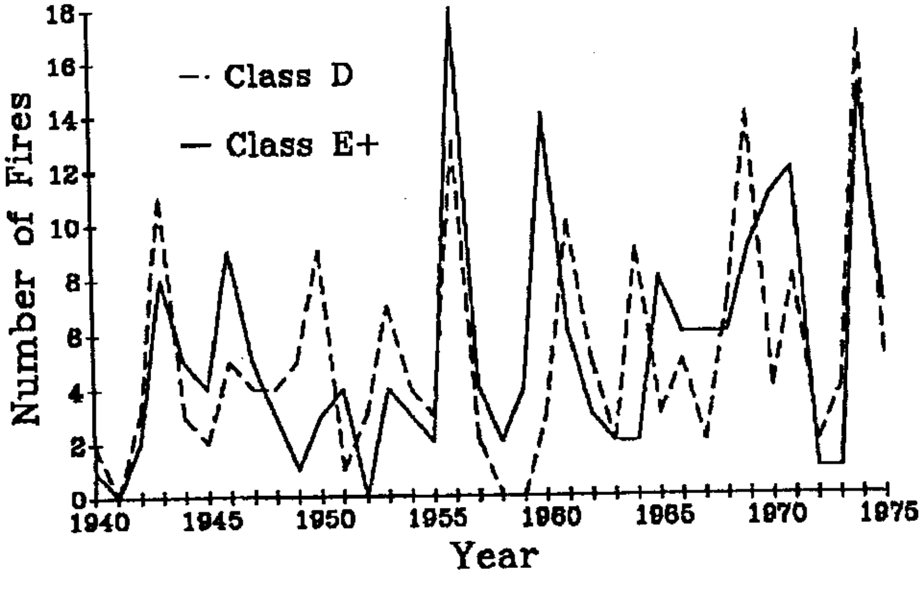

Figure 3.—Number of class D (100 to 299 acres) and class E and larger (> 300 acres) lightning fires in the Southwestern Region (Barrows 1978).

year fires (1-year intervals) have also been noted on rare occasions in some of these sites. The higher fire frequencies in northern Arizona chronologies, with exception of the Chuska Mountains, is clearly visible in figure 5.

The mean recurrence intervals shown in table 1 are primarily useful for comparative purposes. It is most important to consider the historical range and variability of fire occurrence. One example of temporal variability can be seen as an apparent shift in fire regimes to longer fire-free periods beginning in the early and middle 1800s in many of the chronologies (fig. 5). A puzzling gap with few or no fires during a period from about 1820 to 1840 is also noticeable in some of the chronologies. This hiatus may be due to wetter conditions as evidenced by climate reconstructions from tree rings; the 1830s-40s period was apparently one of the wettest in the last two hundred years (Schulman 1956, Fritts 1986). Also, reduction in fire frequency during this period may have been associated with intensified sheep grazing in New Mexico during the 1820s (Denevan 1967). Intensive grazing removes fine grassy fuels important in spreading fires. However, information about mid-19th century stock numbers in southern New Mexico and Arizona is sketchy. The grazing hypothesis may be supported by the fact that many of the fire chronologies recorded a final fire in the late 1800s around the beginning of an intensive grazing era, and 20 years or more before the advent of organized fire suppression efforts by the USDA Forest Service.

The fire scar chronologies also show a remarkable correspondence of fire years across the Southwest (fig. 5). These years are also evident in a fire area index (fig. 6). The fire area index reveals that regional-fire years (labeled years) were often large fires within the sites where they were recorded. The individual chronologies (fig. 5) show that in some cases more than 80% of sampled trees recorded fires during the regional-fire years.

Southwestern Fire and ENSO Events

El Niño-Southern Oscillation (ENSO) events are global-scale climatic anomalies that recur at intervals of 2 to 10 years and at varying intensities (Philander 1983). The El Niño pattern is characterized by weak tradewinds and appearance of high sea-surface temperatures off the western coast of the Americas. The Southern Oscillation is measured as the normalized differences in monthly mean pressure anomalies between Tahiti, French Polynesia and Darwin, Australia. El Niño and the Southern Oscillation are linked in a global climate complex of changing ocean currents, ocean temperatures, atmospheric pressure and temperature gradients. Subcontinetal or regional-scale climatic effects of ENSO events are highly variable. In some cases the effects are consistent and extreme, leading to droughts in some regions and flooding in others.

Table 2.—Changes in annual number of fires by size class (acres). Southwestern Region data include only lightning-caused fires, while Gila National Forest data include lightning and person-caused fires.

	A (0.25 or less)		B(0.26-9)		C+ (10+)	
	Mean	SD	Mean	SD	Mean	SD
Gila National Forest: 1.4 million hectares						
Period						
1909-1939 (31 yrs.)	40	43	16	12	5	5
1960-1980 (21 yrs.)	276	103	79	35	10	10
t-statistic =	11.370		9.190		2.790	
probability =	<0.001		<0.001		0.008	
Southwestern Region: 8.4 million hectares						
Period						
1940-1957 (18 yrs.)	1,063	329	324	100	47	22
1958-1975 (18 yrs.)	1,515	437	307	110	51	31
t-statistic =	3.505		0.460		0.459	
probability =	0.001		0.646		0.649	

Table 3.—Lightning fire data for the Southwestern Region.

Period	No. of fires	Hectares (acres) burned	Hectares (acres) burned/fire
1940-1949	13,858	49,982 (101,266)	2.96 (7.31)
1950-1959	15,709	53,358 (131,846)	3.40 (8.39)
1960-1969	17,363	67,882 (167,733)	3.91 (9.66)
1970-1979	19,925	136,791 (338,006)	6.86 (16.96)
1980-1987	10,716	61,179 (151,171)	5.71 (14.11)

A possible link between ENSO related droughts in the western Pacific and fire is evidenced by massive bush fires in Australia during the 1939 and 1982-83 El Niño events. Also, one of the largest forest fires in history occurred in the tropical forests of the Kalimantan province of Indonesia in 1982. This gigantic fire is estimated to have burned over 3.1 million hectares!

Simard et al. (1985) compared ENSO events to 53-year fire records from large regional areas of the United States and found that only the southeastern region had a statistically significant relationship (inverse) with this climate phenomena. In their study, Arizona and New Mexico were grouped with all the Rocky Mountain and Great Basin states northward to the Canadian border. They noted, however, that this comparison was probably at too coarse a scale, and that smaller and more detailed regional studies may identify stronger relationships.

In the southwestern United States, ENSO events are most consistently related to wetter than average spring and fall seasons (Andrade and Sellers 1988, Betancourt 1988). This condition is due to southward displacement of the jet stream and westerlies in the eastern Pacific and development of tropical storms over the warming waters off the coast of Baja, California. Subsequent anti-cyclonic movement of these storms into northern Mexico, southern Arizona and New Mexico brings an unseasonable influx of moisture to the region during the normally arid spring and fore-summer. This is also the critical burning period in the Southwestern Region (fig. 7).

Figure 8 shows the timing of ENSO events as classified by Quinn et al. (1987) and area burned per year in the Gila National Forest and the Southwestern Region. Differences in mean hectares burned per year between ENSO and non-ENSO years were evaluated using the Mann-Whitney test (table 4). The ENSO event in 1925 appears to be the only outstanding exception to a consistent correspondence of ENSO events and the lowest area burned years (fig. 8). Unlike most ENSO events, the spring of 1925 was actually quite dry, and wetter conditions did not develop in the Southwest until the fall and winter of 1925-26. Note that one of the most severe ENSO events of the past two centuries occurred in 1982 and 1983, when the area burned in the Southwest was the second and third lowest over the past 50 years. The lowest area burned was in the year 1941, another very severe ENSO event.

Initial observations of number of fires recorded per year in relation to ENSO events has yielded inconsistent results. Simard et al. (1985) also noted that these types of data were less clearly related to ENSO than area burned. This may be due to the confounding effect of changing fire-detection and fire-fighting resources. A more complex relationship may also exist with thunderstorm activity and ENSO. For example, increased moisture during some ENSO years may actually result in increased thunderstorm activity which triggers more lightning caused fires, but lower overall area is burned because of higher fuel moisture. Weak or moderate El Niño events also seem to be less clearly associated with reduced southwestern fire activity than severe or very severe events. Again, it seems possible that ignition rates and fuel moisture may be involved. Weak or moderate El Niño events may deliver enough moisture to the Southwest to increase the level of thunderstorm activity but not sufficient moisture to reduce fire spread.

The next ENSO fire comparison utilized the much longer-term perspective of fire-scar chronologies. The two-century record of fire occurrence derived from the five Gila fire-scar chronologies was compared to severe and very severe ENSO events in figure 9. El Niño events for the period prior to the mid-nineteenth century were reconstructed from historic records of droughts, floods, fluctuations in fisheries off the South American coast, and other variables that are known to be closely linked to the El Niño pattern (Quinn et al. 1987).

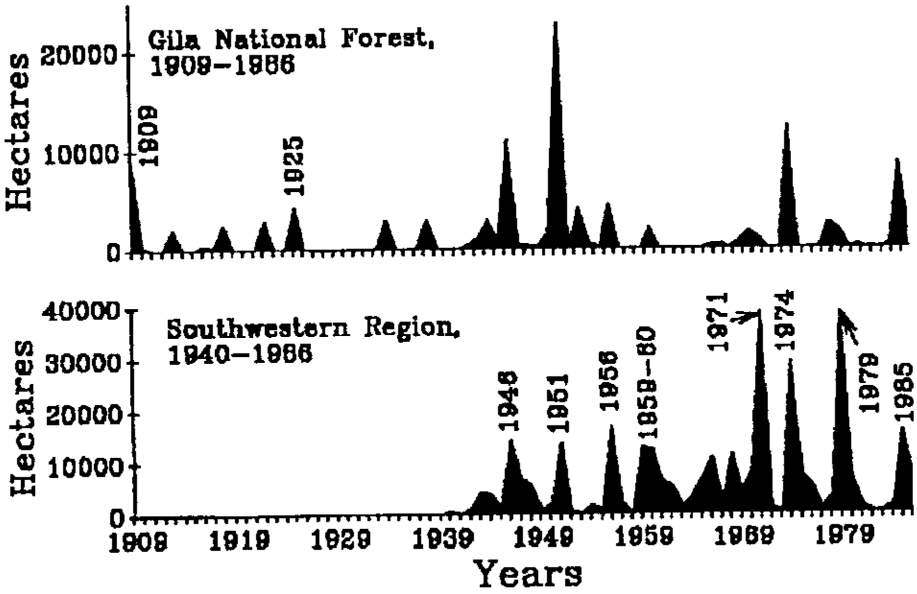

Figure 4.—Area burned per year in Gila National Forest and Southwestern Region. The Gila data include person and lightning-caused fires, while Southwestern Region data include only lightning fires. Major fire years are labeled.

With only a few exceptions the severe ENSO events corresponded to years of reduced fire activity as measured by fire-scarred trees (fig. 9). Another fairly consistent pattern was occurrence of large fire years one or two years following severe ENSO events (fig. 9).

Discussion: Implications for Fire Management

Trends and Extreme Events

Two particular warnings to managers emerge from the study of fire records. The first is a trend of increasing fire load. Evidence of this trend includes higher numbers of large fires in the Gila National Forest in the modern period and larger area burned per lightning-caused fire in the shorter record from the entire Southwestern Region. This trend may indicate that fire control will be an increasingly difficult task in coming years. Possible causes of this trend may be climate change, management practices, or both.

Management practices might promote large fires in several ways. The increased number and extent of roads in southwestern forests provides more access to forest lands. Improved access coupled with increased recreation use beginning in the 1970s may have led to more person-caused fires. Increased fuels and changes in forest structure due to 80 years of relatively effective fire control, especially in pine forests which formerly burned 2 or 3 times per decade, may also have played a role in the apparent increasing trend in lightning fire data. Logging also increases fuel loadings on the forest floor in some types, and opening of canopies in harvested stands might lead to more rapid drying of fuels because of greater insolation.

The second major warning to managers from the fire data analysis is that extreme fire events, or regional-fire years, are part of the fire

Figure 5.—Fire-scar chronologies from the Southwest. Percent trees scarred is the proportion of sampled trees recording a fire relative to the number of fire-scar susceptible trees at that date. Fire-scar susceptible trees are defined as trees that have been previously scarred by at least one fire (Romme 1980). The wide range of variability in fire chronologies is visible. Notice the higher fire frequency in chronologies from northern Arizona (four uppermost plots), and the longer intervals between fires that appear in 1800s in the chronologies further to the south.

regime of southwestern forests. This is not particularly new information to southwestern fire-fighting veterans who remember, for example, the 1956, 1971 and 1974 fire seasons. Nevertheless, consideration of history extending beyond the reach of human memories can serve to verify the existence of this phenomenon, and possibly help identify the probability of its recurrence.

One of the remarkable features of the two-century southwestern fire history represented in the fire-scar chronologies was the synchrony of large fire years among the widely scattered sites. Based on both the Forest Service data base for this century and the fire-scar record extending back to 1700, it appears that at least 3 or 4 regional-fire years occurred per century. The occurrence of extreme regional-fire years suggests that atmospheric conditions were responsible, because these are the only environmental variables that can account for such spatially large-scale phenomena. It is also likely that these conditions were at least partly cumulative through some period of time preceding extreme fire events, and therefore some advance warning may be present. There is clearly a need for further research of historical climate and fire records to pinpoint these conditions.

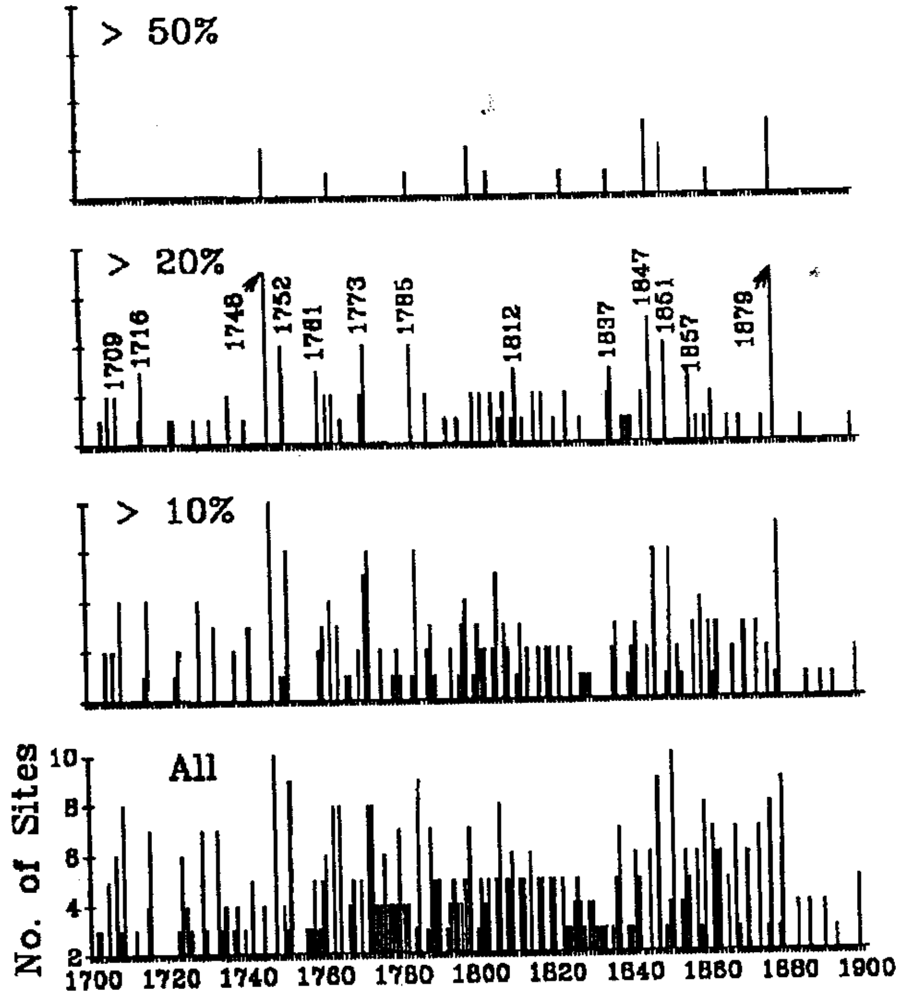

Figure 6.—Fire-area index computed as number of sites (fire-scar chronologies) recording fires per year for the period 1700-1900. Fifteen sites are included. Fires recorded by any tree within the sites are shown in the lowermost plot, while fires recorded by more than 10, 20, and 50% of fire-scar susceptible trees are shown above. Regional fire years are labeled.

Climatic warming is another concern. Regardless of whether or not a warming effect due to increased CO_2 in the atmosphere is already reflected in global weather patterns, there is a building consensus among atmospheric scientists that such an effect, at some unknown intensity, is virtually imminent. Since some of the projected warming scenarios show increasing droughtiness in the southwest (Schlesinger and Mitchell 1985) this effect may also contribute to a worsening fire situation.

From an ecological point of view, the variability in fire regimes is more likely to be important to plant communities than mean values computed for some arbitrary period. For example, unusual long periods without fire may lead to increased establishment of certain species that are intolerant of fire during the first years of life. The co-occurrence of such fire-free periods and wetter climatic conditions may also be extremely important to species with episodic regeneration patterns, such as ponderosa pine. Thus, while statistical summaries of fire chronologies are useful for general comparisons of different forests, fire's influence on the ecosystem is strongly a historical process. Southwestern forests may be more a product of relatively short-term and unusual periods of climate and fire frequency then average or cumulative measures of these long-term histories.

ENSO and Fire

The ENSO-fire teleconnection in the Southwestern Region is clearly inverse, i.e., significantly wetter springs and summers during ENSO events results in a very reduced fire load. Additional work has also shown that the opposite pattern of El Niño, sometimes referred to as La Niña (Kerr 1988), seems to often correspond to peak fire occurrence years (Swetnam and Betancourt, in prep.). The most promising application of these findings would be a predictive tool for anticipating fire season severity. Work by Bradley et al. (1987) and Andrade and Sellers (1988) has shown that temperature and precipitation response in North American records usually lags 3 to 6 months behind the onset of ENSO events as measured by sea-surface temperatures and the southern oscillation. Thus, the ability of meteorologists to predict ENSO conditions during the winter months before a fire season is likely to improve in coming years (Barnett et al. 1988).

What are some of the management implications of such predictive power? One implication would be for the planning and implementation of prescribed burning plans. Prescribed burning during the typical arid spring and foresummer in the Southwest carries an unknown level of risk due to the uncertain timing of arrival of the monsoon pattern later in the summer, and the possibility of extended dry and windy conditions in the interim. Developing ENSO conditions during winter months, especially those suggesting extreme events, may call for stepping up prescribed burning activities in the spring and early summer because the likelihood of drying conditions later in the season would be lower. Likewise, if further research shows a strong link between La Niña conditions and high fire occurrence, it would be advisable to curtail spring and summer burning during such years. Even if the ENSO phenomena does not prove to be a useful predictive tool for southwestern fire managers, the high likelihood that regional-fire years will recur in the southwest strongly indicates that consideration be given to drying trends during previous and current seasons.

Conclusions

Fire occurrence records for pre-1900 periods document the ubiquity of fire in the southwestern landscape for several centuries prior to the beginning of active forest land management and fire suppression. Through time the dynamic effects of surface fires were second in importance only to the change of seasons. Trees that germinated, established and grew through the majority of their lifespan in a fire regime of repeated surface fires still comprise the vast majority of harvestable timber products in the region, as well as contributing to other forest values. From this perspective of the past, managers must assess the ecological consequences of 80 years of fire suppression in forest types that have adapted to fire over many thousands of years. What will our forests look like 100 or 200 years from now if fire does not play the role it did for centuries before our intervention? The fire histories documented by fire-scar studies remain one of the strongest scientific arguments for incorporating fire into the management of southwestern forests. In making management decisions, ecological knowledge of factors important to the healthy functioning of forest ecosystems must also be weighed against practical considerations, such as the generation of smoke and the hazard of escaped fire.

The synchronous occurrence of large fires in many of the widely scattered forests of the Southwest in particular years is an outstanding feature of both pre- and post-1900 fire records. Severe and very severe ENSO events appear to be consistently associated with reduced fire occurrence in the region. Regardless of whether the ENSO-fire teleconnection proves useful for predictive purposes, this finding and the observation of regional-scale fire years argues that, to a large degree, regional climate patterns control year-to-year fire occurrence. A challenge to researchers and managers is to recognize these patterns and to act in time. Recommended actions include continued and increased effort to reduce accumulated fuel loadings through careful use of fire, and consideration of climatic patterns in fire management planning.

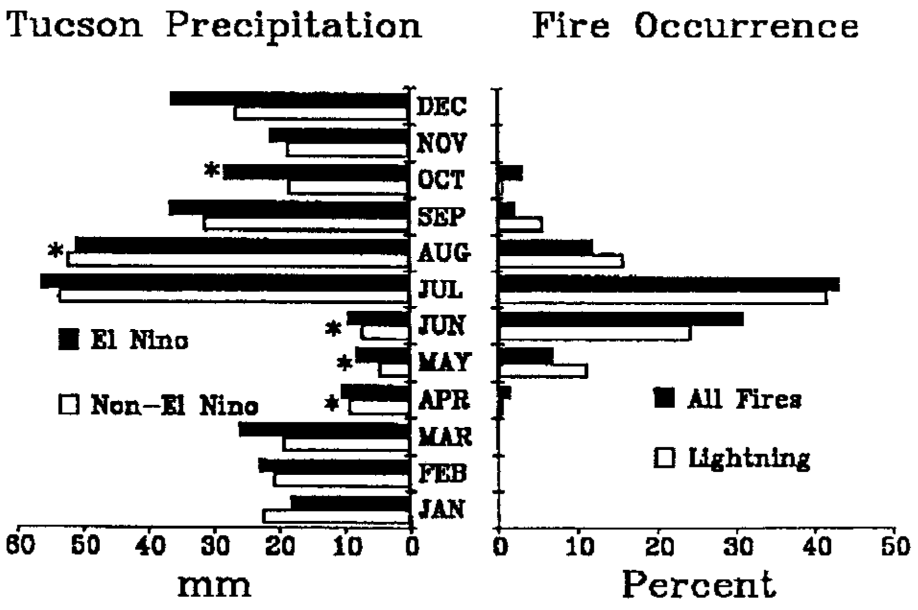

Figure 7.—Distribution of fires by month (1940-1975) in comparison to a precipitation record from Tucson, Arizona (1868-1986). Peak fire activity is during the driest period. Especially critical are the two to three weeks just prior to the "Arizona Monsoon" at the end of June and beginning of July. Wetter months during El Niño years in the winter, spring and foresummer (significant differences indicated with an asterisk, Mann-Whitney test, $p < 0.05$) may explain most of the reduction in area burned per year in the Southwestern Region.

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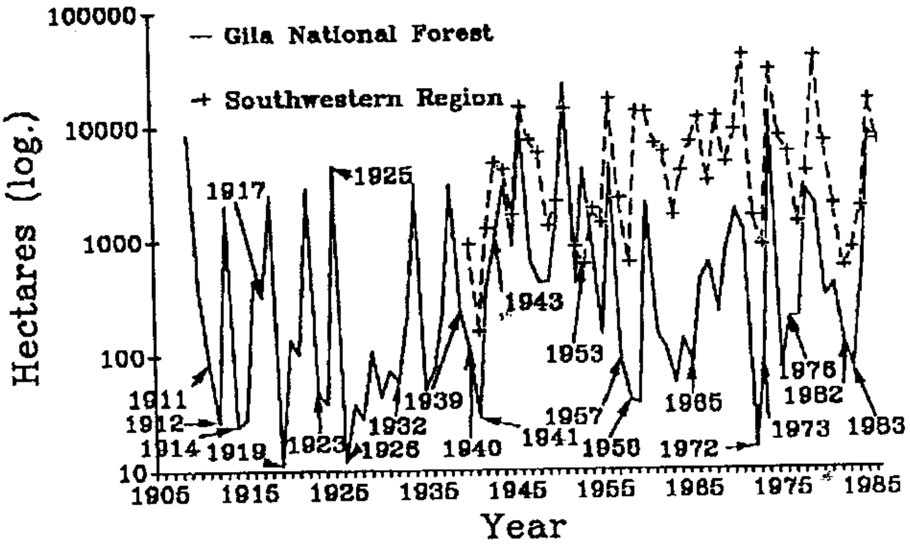

Figure 8.—Area burned per year (logarithmic scale) in Southwestern Region and Gila National Forest in relation to moderate and severe El Niño events. Severe or very severe events according to Quinn et al. (1987) occurred in 1911-1912, 1914, 1917, 1925-1926, 1932, 1940-1941, 1957-1958, 1972-1973, 1982- 1983. All other labeled dates were moderate El Niño

Table 4.—Mean area (hectares) burned during non-El Niño and El Niño events. "n" is number of events included in the grouping and "p" is the two-tailed probability level for Mann-Whitney U test for differences between the means of non-El Niño and El Niño groupings. Intensity of El Niño events was clasified by Quinn et al. (1987) on a scale of weak-moderate, moderate, severe, and very severe corresponding to the groupings below (WM,M,M+,S,S+,VS).

		El Niño years		
Areas	Non-El Niño years	S/S+/VS	M/M+/S/S+/VS	WM/M/M+/S/S+/VS
Gila N.F. (1909-1986)	1,582 n = 52 p < 0.001	387 n = 14 p < 0.001	355 n = 16 p = 0.002	1,412 n = 26
Southwestern Reg. (1940-1986)	8,676 n = 34 p < 0.001	957 n = 8 p = 0.001	2,114 n = 12 p = 0.003	3,013 n = 13

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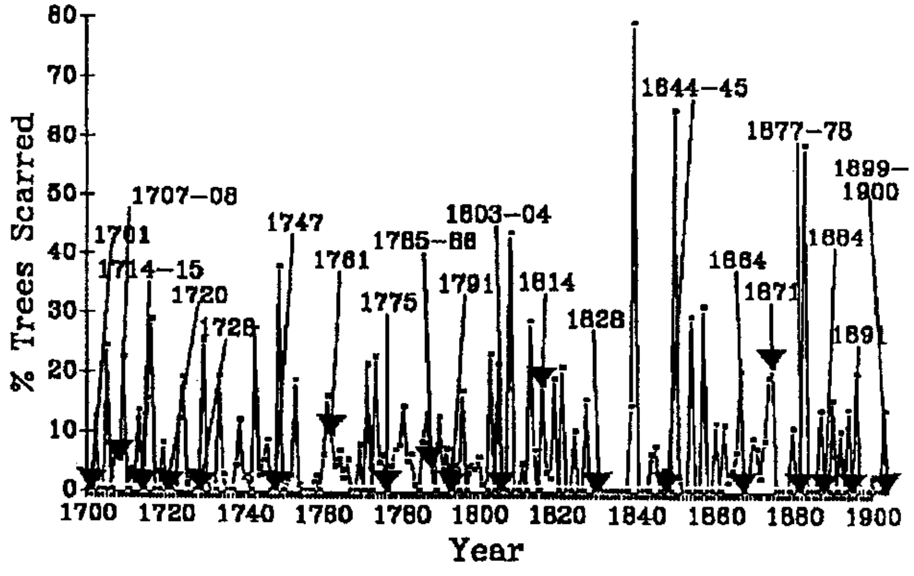

Figure 9.—Severe and very severe El Niño events in relation to percent fire scar-susceptible trees scarred per year from five Gila National Forest chronologies (series 7, 8, 9, 10, and 11 in fig. 1 and table 1). The means for non-El Niño and El Niño years were 6.9% and 3.6% respectively (p = 0.07, Mann-Whitney test).

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