

Relative Impact of Weather vs. Fuels on Fire Regimes in Coastal California¹

Jon E. Keeley²

Abstract

Extreme fire weather is of overriding importance in determining fire behavior in coastal chaparral and on these landscapes fire suppression policy has not resulted in fire exclusion. There is regional variation in foehn winds, which are most important in southern California. Under these severe fire weather conditions fuel age does not constrain fire behavior. As a consequence prefire fuel manipulations have limited impact on fire spread during mass fire events, although strategic placement of fuel modifications may determine the outcome of fires under moderate weather conditions.

Introduction

Natural crown fire regimes include diverse ecosystems from California shrublands to Rocky Mountain lodgepole forests and pose special problems for fire and resource managers. Crown fire ecosystems stand in striking contrast to Southwestern ponderosa pine forests where fire suppression policy has meant fire exclusion from much of that landscape throughout the 20th century (Allen and others 2002). In general, fire suppression activities have not succeeded in excluding fire from many crown fire ecosystems (Keeley and Fotheringham 2001b, Johnson and others 2001). This is illustrated by burning patterns in the coastal ranges of central and southern California (*fig. 1*); clearly, on these landscapes fire suppression policy cannot be equated with fire exclusion.

So why is fire suppression policy in much of the Western U.S. so effective at excluding fires, but incapable of excluding fires on coastal chaparral landscapes? It certainly is not for lack of trying; in California expenditures on fire suppression have steadily increased during the 20th century (Clar 1959, Pyne 1982). Two potential factors are weather and fuels.

Role of Weather

If chaparral wildfires ignite during moderate weather conditions they are readily contained by suppression forces (Herbert Spitzer, County of Los Angeles Fire Department, May 2001). However, it is a different story when they ignite during severe fire-weather conditions, and such conditions are possible year round. In many parts of coastal California, autumn foehn winds known as Santa Anas (*fig. 2*) produce the worst fire weather conditions in the country (Schroeder and others 1964).

¹An earlier version of this paper was presented at the Fire Conference 2002: Managing Fire and Fuels in the Remaining Wildlands and Open Spaces of the Southwestern United States, January 2–5, 2003, San Diego, California.

²Station Leader, U.S. Geological Survey, Western Ecological Research Center, Sequoia National Park, Three Rivers, CA 93271-9651 & Department of Organismic Biology, Ecology and Evolution, University of California, Los Angeles, CA 90095. e-mail: jon_keeley@usgs.gov.

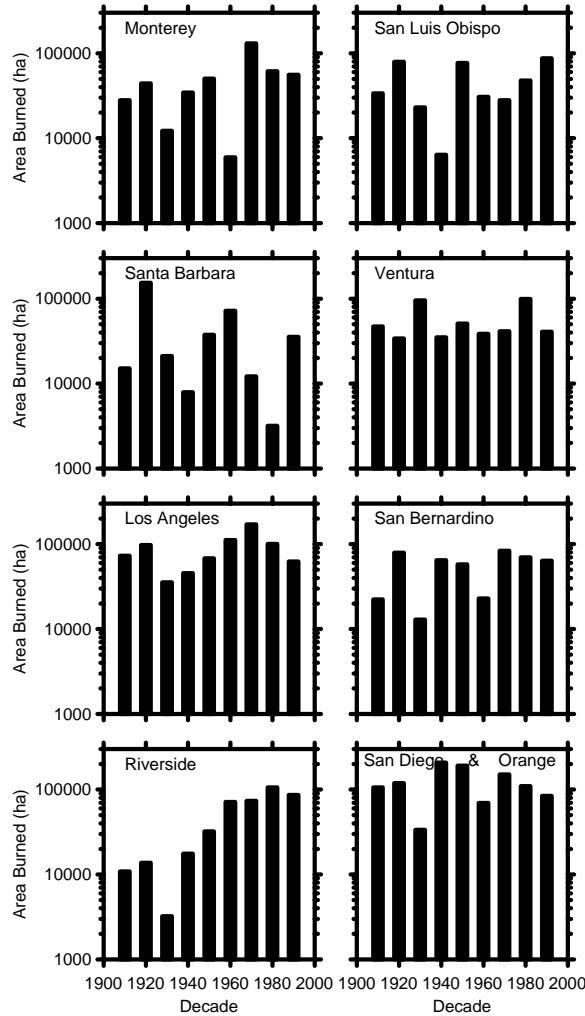


Figure 1—Area burned (log scale) by decade for the nine counties in central coastal and southern California. Data from the Statewide Fire History Data Base, California Department of Forestry, Fire and Resource Assessment Program (FRAP), Sacramento CA, which includes historical fire records from U.S. Forest Service national forests, California Division of Forestry ranger units and other protected areas, plus city and county records; minimum fire size recorded varied with agency from 16 to 40 ha.

While large wildfires throughout the western U.S. are nearly always associated with severe weather conditions (Schroeder and others 1964), southern California Santa Anas are more destructive because they typically follow 6 months or more of drought and, unlike severe fire weather in other parts of the West, Santa Anas are *annual* events. The role of Santa Ana winds is evident when one compares the seasonal distribution of fire in this region with other parts of the country. In the southwestern U.S. both fire occurrence and area burned peak in the summer months (Swetnam and Betancourt 1998), whereas in southern California fire occurrence peaks in early summer but area burned peaks in the autumn (Keeley and Fotheringham 2003).

In the southwestern ponderosa forests the majority of fires are ignited by summer lightning storms (Keeley and Fotheringham 2003), and atmospheric

conditions at the time of ignition slow the initial spread of the fire and provide a window of opportunity for suppression before weather conditions deteriorate. In contrast, the vast majority of chaparral fires are ignited by people and thus are not greatly constrained by season. When ignited during an autumn Santa Ana wind event, they produce wildfires that are virtually unstoppable until the weather changes (Countryman 1974, Pyne 1982). Because these winds are capable of driving fire through young fuels, as well as jumping over such fuels with fire brands that can be carried more than a kilometer beyond the fire front, the ability of fire managers to alter the course of Santa Ana wind driven fires by prefire fuel manipulations, e.g., prescribed fire, is limited (Keeley 2002a).

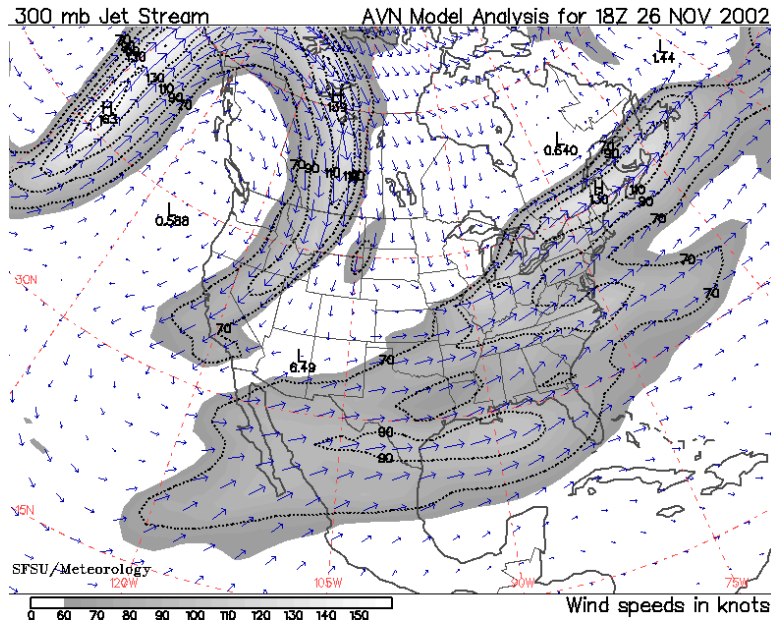


Figure 2—Wind direction during a recent Santa Ana wind event (<http://squall.sfsu.edu/crws/jetstream.html>, accessed 27 Nov 2002). High pressure in the Great Basin coupled with low pressure off the coast creates foehn conditions of high winds, often sustained wind speeds $>100 \text{ km hr}^{-1}$ and relative humidity $<10\%$. Wind direction varies due to local topography (Keeley and Fotheringham 2001a) but in general it is from the north in northern California (where they are known as "northerlies") and more easterly in southern California. South of the U.S. border Santa Ana winds are less predictable and often (as illustrated here) wind direction shifts to onshore flow. The direction most Baja California wildfires burn is from west to east, whereas north of the border large fires burn from east to west (Minnich and Dezzani 1991). Further into Mexico, south of Ensenada and including the San Pedro Martir Mountains, Santa Ana winds are reportedly unknown (Jose Delgadillo, personal communication, January 2002).

In light of the low incidence of lightning fires in coastal California, coupled with the close temporal juxtaposition of late summer lightning fires and autumn Santa Anas, historically the bulk of the chaparral landscape likely burned during Santa Ana events (Keeley and Fotheringham 2003).

In addition to the synoptic weather conditions necessary for Santa Ana wind development, there are many local topographic effects related to the orientation of mountain ranges and presence of low passes to funnel the air downward (Keeley and

Fotheringham 2003). For example, the front side of the Santa Ynez Range above Santa Barbara apparently lacks Santa Ana winds (Moritz 1999). This region does have severe fire weather known as "sundowners," but these local down canyon winds are not annual events like Santa Anas. This lack of Santa Ana winds has resulted in a reduction in large fires relative to the surrounding region (Moritz and others 2004). On the west face of the southern Sierra Nevada, Santa Ana winds likewise fail to develop due to the sharp eastern escarpment, lack of appropriate passes, and diminished influence of the coastal low pressure trough. This is reflected in very different burning patterns relative to southern California. For most of the counties in coastal California fire rotation intervals are 30 to 40 yr (Keeley and others 1999). This contrasts with the southern Sierra Nevada, where 43 percent of chaparral landscape has never had a recorded fire (Keeley and Pfaff unpublished data).

Role of Fuels

The dominant fuels consumed in the surface fire regime of western forests are quite different than in chaparral crown fires. In southwestern ponderosa pine ecosystems natural fires are typically low intensity and are primarily spread by burning surface fuels of sloughed off leaves and branches. Frequent lightning ignitions in these forests are capable, under natural conditions, of consuming fuels at a rate sufficient to greatly reduce the possibility of fire spreading from surface fuels to ladder fuels that connect surface fires with tree canopies. In recent years much of this landscape has experienced an unnaturally long cycle of fire exclusion (Allen and others 2002). This is primarily due to a combination of intense grazing that diminished herbaceous fuels and a fire suppression policy that has successfully extinguished the majority of lightning fires at a relatively small size. The success of fire suppression policy in this region derives from the fact that the types of fuels that carry fire ultimately generate fires that are often easily contained.

In mature chaparral, surface fuels are generally of limited importance because of lower rates of fuel production, and most chaparral shrubs fail to self-prune dead branches. Since fire spread is through slowly accumulating canopy fuels, fire is constrained by stand age and rates of dead fuel accumulation in the canopy. Indeed, experimental manipulations of fuel structure in chamise chaparral have shown that total stand fuel volume is of less importance to fire intensity than fuel structure. Using prescription burns in *Adenostoma fasciculatum* dominated chaparral, Schwilk (2002) demonstrated that if dead branches are cut from the canopy and left on the soil surface, peak fire temperatures at both ground level and 30 cm above ground level dropped from over 250°C in controls to only 100°C. This was not statistically different from treatments where stand fuel volume was altered by removing these dead branches from the site.

Because chaparral fires are not spread by surface fuels, there are greater limitations on the use of prescription burning. Highly productive forests produce sufficient surface fuels to allow low intensity surface fire rotations at 5 yr intervals, greatly decreasing hazard of higher intensity crown fires (Allen and others 2002). Canopy fuels in chaparral seldom will carry prescription burns in stands less than 20 yr of age (Green 1981) and much longer when dominated by scrub oaks and other species that self-prune dead branches (Keeley and Fotheringham 2003). This limitation of prescription burning to mature chaparral stands greatly limits the benefits of prescription burning, as well as increasing the hazards of prescription

burning (Keeley 2002a). These constraints, however, diminish if fires ignite outside the weather limits (of wind and humidity) for prescription burning, if the brush is first mechanically crushed, or if alien grasses invade (Keeley 2002b).

Thus, an important question is to what extent is fire regime controlled by stand age. Minnich (1998, 2001; Minnich and Dezzani 1991) has argued that fire occurrence in chaparral is entirely constrained by the rate of fuel accumulation and thus probability of burning increases with stand age. In order to rectify this model with current estimates of fire rotation intervals, he maintains that chaparral is largely immune to fire until 60 yr of age. However, empirical measures don't support that model. Schoenberg and others (2001) report that in Los Angeles County there is little change in probability of burning in chaparral stands older than 20 yr. Moritz and others (2004) applied the Weibull model to stand age maps for 10 areas from Baja California to Monterey to determine how fire hazard changes with fuel age. In all but one region (coastal Santa Barbara) fire hazard was largely independent of stand age.

The Myth of Fire Suppression Impacts on Southern California Chaparral

In his masterful account of fire history in America, Stephen Pyne (1982) laid out the fundamental paradigm of how fire suppression policy had succeeded in excluding fire from forests of the western U.S. and the subsequent impact of increasing fire hazard in these forested ecosystems. Shortly afterward Minnich (1983) invoked this model to account for differences in fire size north and south of the international border. Subsequently, it has been argued that fire suppression has grossly altered the natural fire regime in southern California chaparral (Minnich 1998, 2001, this volume). This is based on the hypothesis that fire suppression policy has excluded fire from the southern California landscape for a sufficient time to allow unnatural accumulations of fuels.

However, *figure 1* in a sense is a test of Minnich's hypothesis, and clearly it is demonstrated that fire suppression has not *excluded* fire during the era of 20th century fire suppression policy. Historical evidence demonstrates that the effectiveness of fire suppression increased markedly after World War II (Clar 1959, Pyne 1982, Dombeck 2001); however, in coastal California this did not result in dramatic reductions in burning (*fig. 1*). Recently Minnich (2001) has proposed that the reason there is no evidence of fire exclusion throughout the 20th century (*fig. 1*) is because fire suppression forces were effectively excluding fires during the latter decade of the 19th century and that unnatural levels of fuels began accumulating early in the 20th century. Thus, according to his model, all of the burning of the 20th century is an artifact of fire suppression. However, the history of forestry and fire protection in California reveals that fire suppression capabilities were non-existent prior to the 20th century, were weak in the early decades, and developed very gradually through the first half of the 20th century (Brown and Show 1944, Clar 1959, Pyne 1982).

In summary, large wildfires that threaten the urban/wildfire interface are a natural feature of this landscape. There is an abundance of historical evidence demonstrating large chaparral wildfires on the order of 10,000 to 100,000 ha occurred long before the fire suppression policy of the 20th century (Pyne 1982, Keeley and Fotheringham 2003, Keeley and others 2004). Prefire fuel manipulations have relatively limited ability to alter the course of such events. It is imperative that

fire managers and scientists better educate the public on the inherent limitations to reducing fire hazard on these landscapes.

References

- Allen, C.D.; Savage, M.; Falk, D.A.; Suckling, K.F.; Swetnam, T.W.; Schulke, T.; Stacey, P.B.; Morgan, P.; Hoffman, M.; Klingel, J.T. 2002.** Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. *Ecological Applications* 12: 1418–1433.
- Borchert, M.I.; Odion, D.C. 1995.** Fire intensity and vegetation recovery in chaparral: a review. In: Keeley, J.E.; Scott, T., eds. *Brushfires in California wildlands: ecology and resource management*. Fairfield, WA: International Association of Wildland Fire; 91–100.
- Brown, W.S.; Show, S.B. 1944.** California rural land use and management: a history of the use and occupancy of rural lands in California. Berkeley, CA: California Region, Forest Service, U.S. Department of Agriculture.
- Clar, C.R. 1959.** California government and forestry-I. Sacramento, CA: Division of Forestry, Department of Conservation, State of California.
- Dombeck, M. 2001.** How can we reduce the fire danger in the interior West? *Fire Management Today* 61: 5–13.
- Johnson, E.A.; Miyanishi, K.; Bridge, S.R.J. 2001. **Wildfire regime in the boreal forest and the suppression-fuel build-up idea.** *Conservation Biology* 15:1554-1557.
- Keeley, J.E.; Fotheringham, C.J.; Morais, M. 1999.** Reexamining fire suppression impacts on brushland fire regimes. *Science* 284: 1829–1832.
- Keeley, J.E.; Fotheringham, C.J. 2001a.** Historic fire regime in southern California shrublands. *Conservation Biology* 15: 1536–1548.
- Keeley, J.E.; Fotheringham, C.J. 2001b.** History and management of crown-fire ecosystems: a summary and response. *Conservation Biology* 15: 1561–1567.
- Keeley, J. 2002a.** Fire management of California shrubland landscapes. *Environmental Management* 29: 395–408.
- Keeley, J.E. 2002b.** Fire and invasives in mediterranean-climate ecosystems of California. In: Wilson, T.P.; Galley, K.E.M., eds. *Proceedings of the invasive species workshop: the role of fire in the control and spread of invasive species*. Tallahassee, FL.: Tall Timbers Research Station; 81–94.
- Keeley, J.E.; Fotheringham, C.J. 2003.** Impact of past, present, and future fire regimes on North American Mediterranean shrublands. In: Veblen, T.T.; Baker, W.L.; Montenegro, G.; Swetnam, T.W., eds. *Fire and climatic change in temperate ecosystems of the western Americas*. New York: Springer; 218–262.
- Keeley, J.E.; Fotheringham, C.J.; Moritz, M. 2004.** Lessons from the 2003 wildfires in southern California. *Journal of Forestry* 102: 26–31.
- Minnich, R.A. 1983.** Fire mosaics in southern California and northern Baja California. *Science* 219: 1287–1294.
- Minnich, R.A. 1998.** Landscapes, land-use and fire policy: Where do large fires come from? In: Moreno, J.M., ed. *Large forest fires*. Leiden, The Netherlands: Backhuys; 133–158.
- Minnich, R.A. 2001.** An integrated model of two fire regimes. *Conservation Biology* 15: 1549–1553.

- Minnich, R.A.; Dezzani, R.J. 1991.** Suppression, fire behavior, and fire magnitudes in Californian chaparral at the urban/wildland interface. In: DeVries, J.J., ed. California watersheds at the urban interface. University of California, Davis; 67–83.
- Moritz, M.A. 1999.** Controls on disturbance regime dynamics: fire in Los Padres National Forest. Ph.D. dissertation. Santa Barbara, CA: University of California.
- Moritz, M.A.; Keeley, J.E.; Johnson, E.A.; Schaffner, A.A. 2004.** Testing a basic assumption of shrubland fire management: How important is fuel age? *Frontiers in Ecology and the Environment* 2: 65–70.
- Pyne, S.J. 1982.** Fire in America: a cultural history of wildland and rural fire. Princeton, NY: Princeton University Press.
- Schroeder, M.J.; Glovinsky, M.; Hendricks, V.H. 1964.** Synoptic weather types associated with critical fire weather. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 492 p.
- Schwilk, D.W. 2002.** Plant evolution in fire-prone environments. Stanford, CA: Stanford University; Ph.D. dissertation.
- Swetnam, T.W.; Betancourt, J.L. 1998.** Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. *Journal of Climate* 11: 3128–3147.

This page intentionally left blank.