An Analysis of Large Chaparral Fires in San Diego County, California

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Abstract—*San Diego County, California, holds the records for the largest area burned and greatest number of structures destroyed in California. This paper analyzes 102 years of fire history, population growth, and weather records from 1910 through 2012 to examine the factors that are driving the wildfire system. Annual area burned is compared with precipitation during the winter preceding the summer–fall fire season and with a five-year running average precipitation. All fires over 4 000 ha from 1950 through 2012 are examined for fuel age at the section of origin, fuel type, and weather, including the presence or absence of foehn winds. The burning characteristics between chaparral and Coastal sage scrub are examined. Annual precipitation was found to have no relationship to the annual area burned. Population increased over 50 times but mean area burned showed no statistical increase. Young chaparral (>20 years)age was shown to constrain the spread or wildfire while coastal sage scrub showed less resistance to fire at any age. Old age chaparral was significant of large wild fires.*

Keywords: *chaparral, conflagration, fire behavior, fire history, fuel age*

Introduction

San Diego County, California USA, holds many dubious records in the history of California wildfires, including the largest fire by area and greatest number of structures destroyed in a single fire (Cedar Fire 2003; 110 579 ha or 273 250 acres; 4 847 structures). Unfortunately, wildland fire policy is heavily influenced by anecdotal evidence and "common sense." Annually, the press is filled with predictions of a severe fire season. Yet not all fire seasons are severe. Not all drought years or years with strong foehn-type winds result in destructive fires. Some observers blame changing climate for large fires, but are climate and large fires related in southern California? In this paper, I attempt to answer that question by analyzing 102 years of fire history and weather records from 1910 through 2012 to examine the factors that drive the chaparral wildfire regime.

I compared the annual area burned with precipitation occurring during the water year preceding the summer-fall fire season and also with a five-year running average water year precipitation. All fires over 4 000 ha from 1950 through 2012 were examined for fuel age near the fire's origin, fuel type at that location, and weather including the presence or absence of foehn winds. The alignment of the topography of San Diego County with normal sea breeze and foehn winds may also help explain the spread of some large fires.

Objectives

The objectives of this project are to: 1) determine if young chaparral has constrained the spread of wildfires based on the historical database of the California Department of Forestry and Fire Protection (FRAP 2012); 2) quantify the relationship of annual precipitation to summer fire season severity; 3) investigate the relation of increasing human population density to anthropogenic area burned; and 4) analyze the similarities and differences between shrubland fuels.

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Materials and Methods

Study Area: San Diego County

San Diego County, California, is the most southwestern county in the United States. It is bordered by Mexico to the south, Imperial County to the east, Riverside and Orange Counties to the north, and the Pacific Ocean to the west. Elevation ranges from sea level to over 1990 m (6 500 feet) along the peninsular range in the eastern county before dropping to below 200 m (600 feet) in the eastern desert. The climate is Mediterranean, with warm dry summers and moist cool winters. Mornings in spring and summer are characterized by a strong marine, atmospheric boundary layer along the coast that usually dissipates by late morning. Climate zones are as follows:

- **Maritime**. Lands generally less than 150 m (500 ft) elevation, within 13 km (8 mi) of the coast, dominated by ocean conditions, moderate temperatures and coastal fog.
- **Coastal plain.** Lands 13 to 50 km (8 to 30 mi) from the coast with less maritime influence and increasing diurnal and seasonal temperatures.
- **Transitional.** Also called the inland valleys and foothills with elevations up to 1200 m (4 000 ft) and diurnal and seasonal temperatures greater than the coastal plain.
- **Interior or Mountain.** Much diminished marine influence, air is warm and dry in summer with poor overnight

Table 1—Generalized Vegetation Cover Type.

Cover Type	Hectares	Acres	Percent
Chaparral	341 847	844 692	55
Coastal Sage Scrub	115 657	285 785	19
Coniferous Forest	6 273	15 500	1
Grasses	79 959	197 576	13
Mixed Conifer/Hardwood Woodland	17 858	44 127	3
Oak Woodland	58 810	145 318	9
TOTAL	620 404	1 532 997	100

(California Land Cover Mapping and Monitoring Program. 1997)

humidity recovery, winter snows, and the marine layer is rare in summer.

- **Desert.** Extreme temperatures, strong winds, and dry air.

The county is divided into three general zones; the coastal plain, inland mountains, and desert. Northeast/southwest trending rivers drain the mountains to the coast. The county is seismically active with two major active faults, the Elsinore and the San Jacinto in the mountain regions, and the San Andreas near the Salton Sea, east of the county.

Native vegetation (excluding desert) covers 620 404 ha (1 533 050 acres) or 55 percent of the total county. Of that area, shrublands comprise about three quarters of all burnable lands (74% - 457 503 ha or 1 130 514 acres) (Table 1).

History

The area presently called San Diego County has been inhabited by humans for over 10 000 years. At the time of European contact, numerous tribes lived, hunted and gathered here including the Kumeyaay in the south, the Luiseño at the north coast and the Cahuilla and Cupeño in northern inland and desert portions. These Native Americans hunted small game, gathered acorns and seeds, fished, and used fire to manage the lands. While it is debatable how much the Native American contributed to the state of the vegetation at the point of European contact, it is safe to say that they did cause frequent fire ignitions that likely had a major impact on the vegetation patterns (Biswell 1974; Anderson 2006; Stewart 2002; Lightfoot 2009). The Governor's proclamation in 1793 is illustrative:

> *"With attention to the widespread damage which results...I see myself required to have the foresight to prohibit...all kinds of burning, not only in the vicinity of the towns, but even at the most remote distances... Therefore I order...to take whatever measures they may consider requisite and necessary to uproot this very harmful practice of setting fire to pasture lands...and in case some burning occurs, they are to try immediately to...stop the fire, or failing that, to direct it into another direction which may result in less damage... "*
>
> Given in Santa Barbara, May 31, 1793.
>
> Don Jose Joaquin de Arrillaga, captain of cavalry, interim governor and inspector comandante of Upper and Lower California (Arrillaga 1793).

The arrival of the Spanish brought many changes to San Diego. European annual grasses and forbs replaced many of the native herbs and forbs. Cattle and sheep grazed the pastures, roads and farms acted as firebreaks, and Indians were removed to reservations (Wade 2009). Fire exclusion became the norm and in 1910, the Forest Service, followed by the California Division of Forestry, began active fire suppression. Simultaneously, burning by ranchers to increase grass production was halted. The changes in the chaparral and forest ecosystem were gradual. Likely, the mosaic of uneven aged fuels initially acted to retard the growth of fires. By the 1920s, large fires were becoming common (FRAP 2012).

Precipitation

Monthly precipitation records are available for the San Diego's Lindbergh Field dating back to 1850. For this study, precipitation data were converted from calendar years to water years (October 1 through September 30) (WRCC 2014). Precipitation occurs in the winter, usually beginning in late October through April, and falling as rain except in the mountains above 1200 m (4000 ft) (Figure 1). Monsoon type summer thunderstorms occur mostly in the mountains and deserts but occasionally spread to the coast. Rainfall is highly variable. The annual average for the period 1910-2012 recorded at Lindbergh Field, San Diego, was 257 mm (10.12 in) with a maximum of 636 mm (25.04 in), minimum 84 mm (3.31 in), and standard deviation of 106 mm (4.17 in). Average annual precipitation was 250 mm (9.84 in) on the coastal plain, 400 mm (15.75 in) in the inland valleys, 575 mm (22.64 in) in the interior, 920 mm (36.22 in) on the higher mountains, and 1100 mm (43.31 in) on south facing Palomar Mountain (SanGIS/SANDAG 2004).

Precipitation records are available from 1948 through 2006 for Campo, CA (WRCC 2014a) and Lake Cuyamaca Dam (WRCC 2014b). Simple linear regression showed a strong relationship between Lindbergh, Campo (R^2 = 0.16, P = 0.0018), and Cuyamaca Dam (R^2 = 0.21, P = 0.0003).

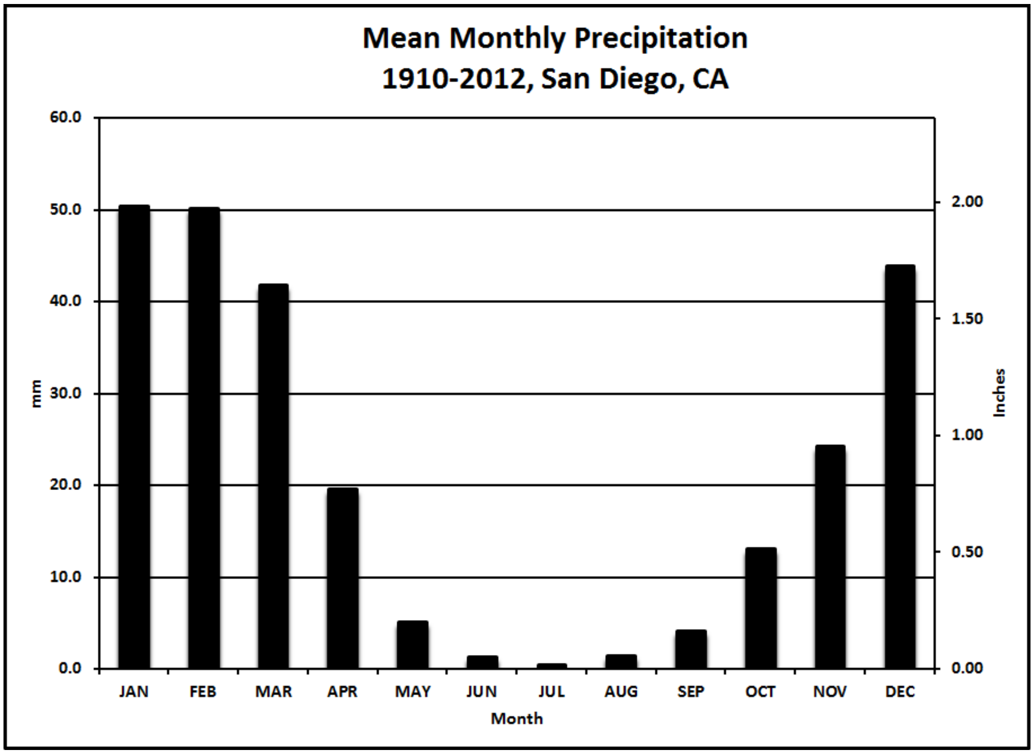

Figure 1—Annual Precipitation at San Diego Airport (Lindbergh Field).

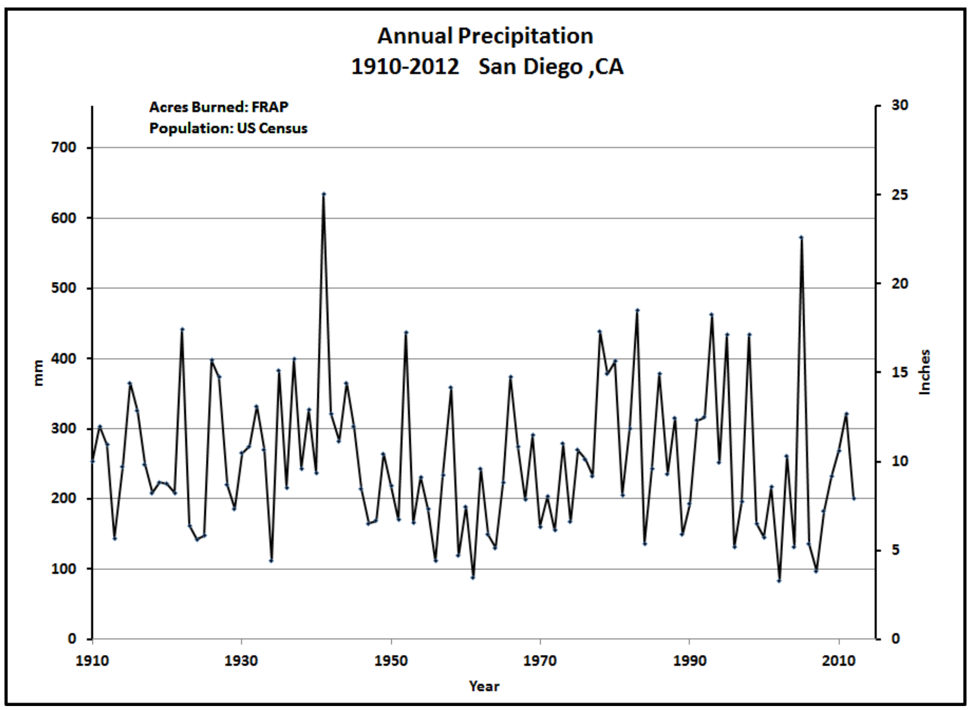

Figure 2—Mean precipitation = 256.8 mm (10.11 inches).

Thus, data from Lindbergh Field can be used as a surrogate for determining wet or dry years for the entire county's burnable areas (Figure 2).

Fire Weather

Large fires occur generally during foehn (Santa Ana) wind events or during Pacific High heat waves. Santa Ana winds, caused by high pressure in the Great Basin, may occur in southern California during the fall, winter, and spring. They do not generally occur in July, August and early September (Figure3) (Countryman 1974; Raphael 2003; Minnich and Chou 1997). Due to compressional heating of air as it descends over the mountains toward the coast, Santa Ana winds are generally hot and dry. However, regression analysis of the number of Santa Ana events (mean = 20; P = 0.666) or the duration of the events (mean 1.5 days; P = 0.195) shows no correlation with annual area burned.

Table 1—*Number of Santa Ana periods by months southern California 1951-60*

Month	Frequency	Average days
September	11	4.4
October	19	4.5
November	26	5.0
December	18	3.7
January	7	1.7
February	10	1.9
March	17	2.5
April	8	1.8
May	7	1.4
June	4	4.5
July	2	2.5
August	0	0

Figure 3—Santa Ana wind frequency by month from Countryman 1974.

Table 2—Area Burned by Primary Fire Spread Driver.

Spread type	Area Burned		Percent
	Hectares	Acres	
Fuel	92 750	229 181	17
NE wind	256 871	634 718	48
Wind Maxima	14 273	35 267	3
Wind/Fuel	169 142	417 944	32
Total	533 035	1 317 110	100

Another weather pattern that heightens fire danger in San Diego County is the summer heat wave, which is caused by an area of high pressure over the western United States resulting in high temperatures, low humidity and unstable air (Schroeder and Buck 1970).

Monsoonal moisture from the Gulf of California can produce dry lightning that can ignite more fires than suppression forces can hold during initial attack. Lightning fires tend to be in remote, roadless areas that increase the complexity of successful initial attack. Low level wind maxima (low level jet) winds were responsible for large fire spreads on August 22, 1969 (Ryan and others 1971) (Table 2).

For our purposes in this analysis, fires over 4 000 ha since 1950 were classified as to fuel driven, wind driven, or both. Fuel driven may, in actuality, mean "not wind driven" as topography may play a large role and in some cases fuel driven is synonymous with plume dominated fires. The wind/fuel class was added for fires after 2003 when the first day of burning was foehn wind driven followed by three hot dry days of prevailing southwesterly winds. The Cedar Fire of 2003 first spread to the west, then winds reversed. The heel of the fire became the head and spread fire to the east until it reached the 2002 Pines burn and halted (Johnson, 2003).

Population Growth

Some have suggested that the increase in population is responsible for the alleged increase in area burned. Since 1910, the population of San Diego County has increased 50 times. Annual area burned shows no statistically significant increase (Figure 4).

Vegetation

Over 600 000 ha (1.5 million acres) of native vegetation covers San Diego County east of the urbanized area and west of the desert. Fingers of vegetation extend into the developed areas as riparian areas and open space. Approximately 70% of the eastern county is owned by the public and administered by the Cleveland National Forest, US Bureau of Land Management, US Fish and Wildlife Service, California Department of Fish and Wildlife, California State Parks, San Diego County Parks, and others. The majority of these public lands are managed for environmental, open space, and recreational use (SanGIS 2013).

The predominant vegetation type is chaparral, followed by soft chaparral or coastal sage scrub (CSS). While they are both shrub-type plant communities and have been considered together by some, they are distinctly different in their burning characteristics (Keeley 2005). The time since last fire needed for chaparral and CSS to become capable of propagating fire is significantly different. CSS shrubs are contiguous from the ground to the tops of the crowns and burn similar to grass. Chaparral shrubs have a distinct crown with fine litter on the ground. Chaparral burns in a continuous crown fire but as burning conditions moderate, fire will drop to the ground and stop spreading.

Healthy CSS communities can grow back in 5 to 10 years, usually interspersed with grass, and can be reburned after five years of post-fire growth. (Figures 5 and 6). That is not the case with chaparral. Young chaparral commonly does not grow with an understory of grass, its young leaves are relatively moist, and there is little to no fine dead fuel on the plant. In the absence of high winds and very low humidity, young chaparral (<20 years) will not carry fire. (Figure 7) As chaparral ages, the amount of fine dead fuel on the shrub increases, which increases flammability (Figure 8) (Hanes 1980; Green 1981; Ottmar and others 2000).

Many analyses of fire history treat fire as a binary system—an area either burns or it doesn't burn. Chaparral burns with varying spread rates and intensities that are related to the age of the vegetation and the current weather. Young chaparral (<20 years) constrains fire spread except during periods of very strong winds with low humidity (Green 1981). Minnich and Chou (1997) found that "Fires burning in old growth tend to cease spreading when they move into adjoining younger stands for lack of fuel."

Fire spread rate is a function of the foliage and fine fuels while heavier fuels contribute to fire intensity (Andersen 1982). Ottmar and others (2000) showed that the ratio of live to dead fuel biomass on 14 year old coastal sage scrub was similar to 30 year old stands. The live to dead fuel mass for young chaparral was about 3:1, while old chaparral was 1:1 (Table 3).

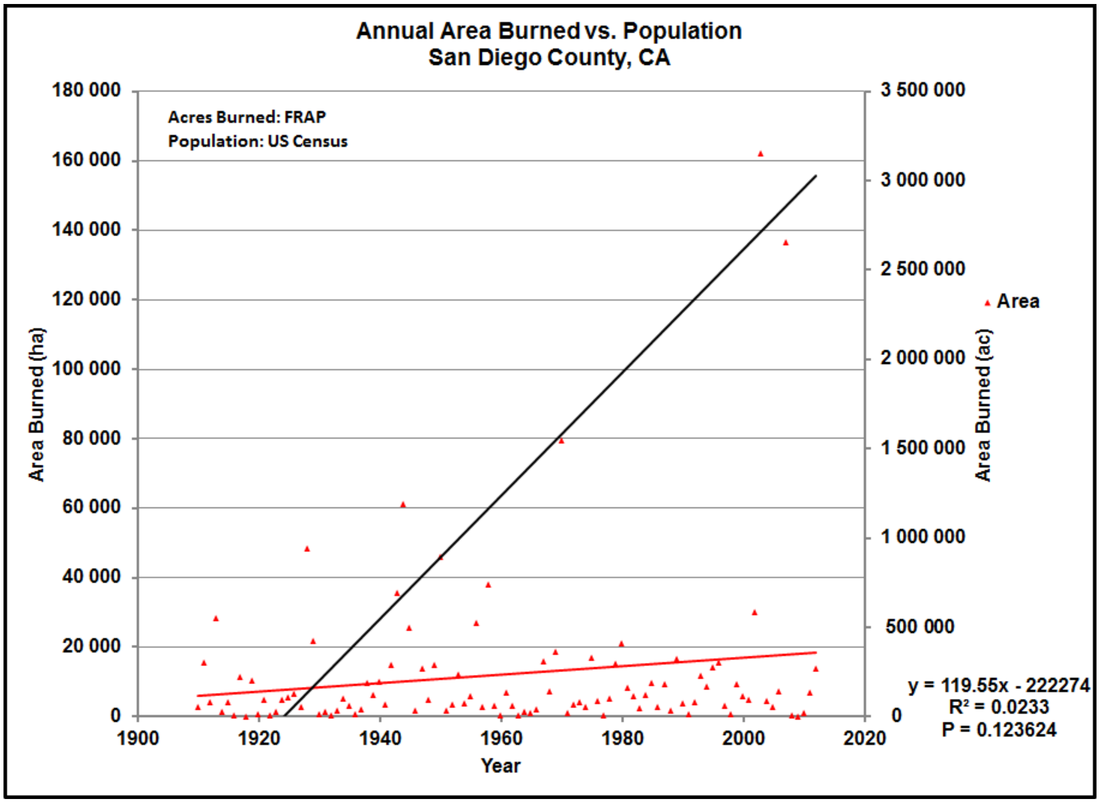

Figure 4—Significant growth in population compared to a non-significant growth in area burned.

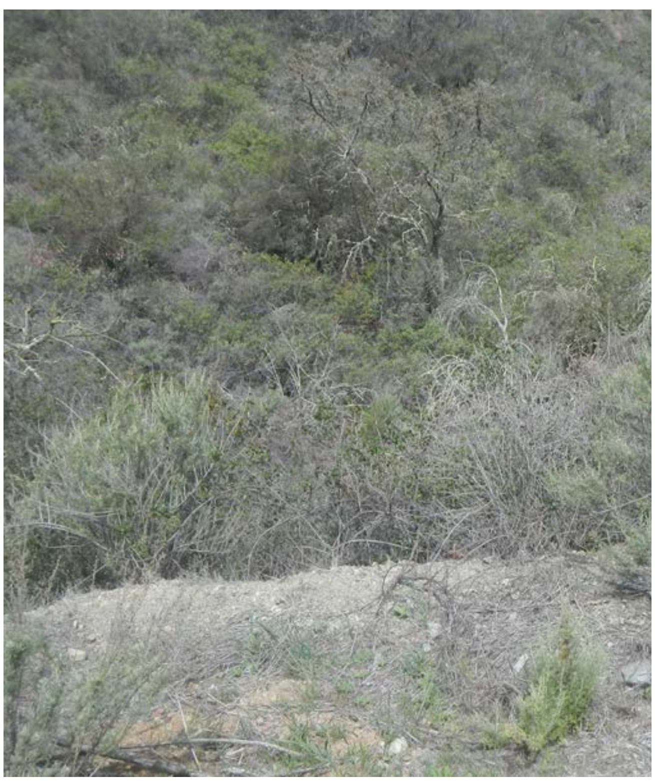

Figure 5—Young coastal sage scrub (7 years).

Fuel Age of Large Fires

The area of origin of thirty three fires over 4 000 ha (10 000 acres) during the period 1950 through 2012 was obtained from a master's thesis used by the County of San Diego to compile early fire history maps (Krausmann 1981). The type of the fuel at the origin was obtained from historic fire perimeters provided by FRAP. Some fire origins were in Riverside County for fires that burned into northern San Diego County. Four fires with ambiguous origins were not included in the study. Twenty fires had no previous fire history recorded and were logged as "greater than." (FRAP 2014).

Results and Discussion

Precipitation

Regression analysis was applied to estimate acres burned as a function of precipitation during the winter preceding the fire season. Because some have suggested that the wildfire area burned is a function of rainfall two years prior, or that long-term drought may increase area burned, regression analysis was applied to both one and two years prior to fire year. No relationship was found. Annual rainfall vs. area burned: $R^2 = 0.023$, P = 0.227, preceding year annual precipitation: $R^2 = 0.0014$, P = 0.563, and five year running average precipitation: $R^2 = .003$, P = 0.951.

A similar analysis was completed for Santa Barbara County and the Santa Monica Mountains. Results were

Figure 6—Old coastal sage scrub (30 plus years). Pole is 5 ft. (1.5 m).

Figure 7—Young chamise seven years since last fire. Parent plant skeleton suggest future growth size. Shovel for scale.

similar: Santa Barbara County: $R^2 = 0.0003$, $P = 0.812$; Santa Monica Mountains: $R^2 = 0.016$, $P = 0.307$.

Vegetation Age and Fire Spread

Four examples illustrate young age chaparral constraining the spread of wildfires.

The Pine Hills fire

At approximately 0600 on October 30, 1967 strong Santa Ana winds blew down a power line east of the community of Pine Hills (1 340 m or 4 400 ft), near Julian, CA during a typical foehn wind event in San Diego with strong (~15m s^{-1} or 30 m h^{-1}) dry winds out of the northeast, relative humidity in single digits, and hot daytime temperatures. The fire spread rapidly through two youth camps, skirted the south end of the community of Pine Hills and destroyed one residence. It crossed Boulder Creek Road and entered the steep, rugged, and road-less Cedar creek drainage area (Schroeder 1968).

Two hours after the Pine Hills fire started, another fire broke out near the Ramona Airport (425 m or 1 400 feet), 26 km (16 miles) west of the Pine Hills fire. In spite of being within a mile of an air tanker base, the fire escaped initial attack and spread rapidly through grass and old chaparral, climbed the eastern slopes of 882 m (2 900 feet) high Mt. Woodson, then headed downslope towards the community of Poway (Figure 9).

The Woodson Fire eventually blackened 12 060 ha (29 800 acres), destroyed 29 houses, and resulted in the first countywide mobilization of municipal firefighting resources for a wildland fire. The Pine Hills Fire was officially contained three days later after burning 2 870 ha (7 090 acres) (Figure 10).

Why did the Woodson fire burn four times the area as the Pine Hills fire?

Wind? Both fires were pushed by strong Santa Ana winds. The higher elevations tended to have longer duration of stronger winds than did lower elevations due to the effect of the afternoon sea breezes.

Temperature? Dry adiabatic compression rates would indicate about 6 °C higher temperatures at Ramona compared to Julian, but this difference is not significant to fire spread according to the Rothermel model (Rothermel 1972).

Access for firefighting? The Pine Hills fires burned into an area inaccessible to engines and too steep for dozers. The Woodson fire burned through the flat Ramona valley and down into Poway, a suburban community with ranch style homes, avocado groves, and a well-developed road network.

Figure 8—Over 100 year old scrub oak (*Quercus* sp.), ca. 25% alive. Trekking pole for scale.

Table 3—Vegetation Biomass—Coastal Sage Scrub and Chaparral.

Coastal Sage Scrub		**Loading (tons/ac) by size class (in) (live/dead)**				
14 years (Ch 02)		**Foliage**	**≤ 0.25 in**	**0.26–1.0 in**	**1.1–3.0 in**	**Total**
	Artemisia californica	0.1 (0.1/—)	0.4 (0.3/0.1)	0.1 (0.1/0.0)	0.0 (0.0/0.0)	0.6 (0.5/0.1)
	Encelia californica	0.0 (0.0/—)	0.5 (0.3/0.2)	0.1 (0.1/0.0)	0.0 (0.0/0.0)	0.6 (0.4/0.2)
	Eriogonum cinereum	0.3 (0.3/—)	1.4 (0.4/1.0)	0.1 (0.1/0.0)	0.0 (0.0/0.0)	1.8 (0.8/1.0)
	Salvia leucophylla	0.3 (0.3/—)	3.1 (2.0/1.1)	1.5 (1.3/0.2)	0.0 (0.0/0.0)	4.9 (3.6/1.3)
	Total	0.7 (0.7/—)	**5.4 (3.0/2.4)**	**1.8 (1.6/0.2)**	0.0 (0.0/0.0)	7.9 (5.3/2.6)
30 years (Ch 01)	**Species**					
	Artemisia californica	0.4 (0.4/—)	2.5 (1.2/1.3)	1.2 (0.8/0.4)	0.1 (0.1/0.0)	4.2 (2.5/1.7)
	Encelia californica	0.0 (0.0/—)	0.1 (0.1/0.0)	0.0 (0.0/0.0)	0.0 (0.0/0.0)	0.1 (0.1/0.0)
	Hazardia squarrosa	0.0 (0.0/—)	0.1 (0.1/0.0)	0.0 (0.0/0.0)	0.0 (0.0/0.0)	0.1 (0.1/0.0)
	Salvia leucophylla	0.2 (0.2/—)	0.8 (0.4/0.4)	0.4 (0.3/0.1)	0.1 (0.1/0.0)	1.5 (1.0/0.5)
	Salvia mellifera	0.2 (0.2/—)	0.3 (0.2/0.1)	0.3 (0.3/0.0)	0.0 (0.0/0.0)	0.8 (0.7/0.1)
	Total	0.8 (0.8/—)	**3.8 (2.0/1.8)**	**1.9 (1.4/0.5)**	0.2 (0.2/0.0)	6.7 (4.4/2.3)
Chaparral						
13 years (Ch 08)	**Species**					
	Adenostoma fasciculatum	2.6 (2.6/—)	3.4 (2.6/0.8)	5.1 (3.9/1.2)	0.2 (0.2/0.0)	11.3 (9.3/2.0)
	Arctostaphylos glandulosa	0.8 (0.8/—)	0.5 (0.4/0.1)	0.9 (0.6/0.3)	0.0 (0.0/0.0)	2.2 (1.8/0.4)
	Ceanothus crassifolius	0.0 (na/—)	0.0 (na/na)	0.0 (na/na)	0.0 (na/na)	tr (na/na)
	Total	3.4 (3.4/—)	**3.9 (3.0/0.9)**	**6.0 (4.5/1.5)**	0.2 (0.2/0.0)	13.5 (11.1/2.4)
55 years (Ch 09)	*Adenostoma fasciculatum*	1.0 (1.0/—)	3.3 (1.8/1.5)	4.8 (3.1/1.7)	4.8 (4.8/0.0)	13.9 (10.7/3.2)
	Arctostaphylos glandulosa	0.4 (0.4/—)	0.6 (0.2/0.4)	1.4 (1.0/0.4)	1.3 (1.3/0.0)	3.7 (2.9/0.8)
	Total	1.4 (1.4/—)	**3.9 (2.0/1.9)**	**6.2 (4.1/2.1)**	6.1 (6.1/0.0)	17.6 (13.6/4.0)

From Ottmar and others 2000.

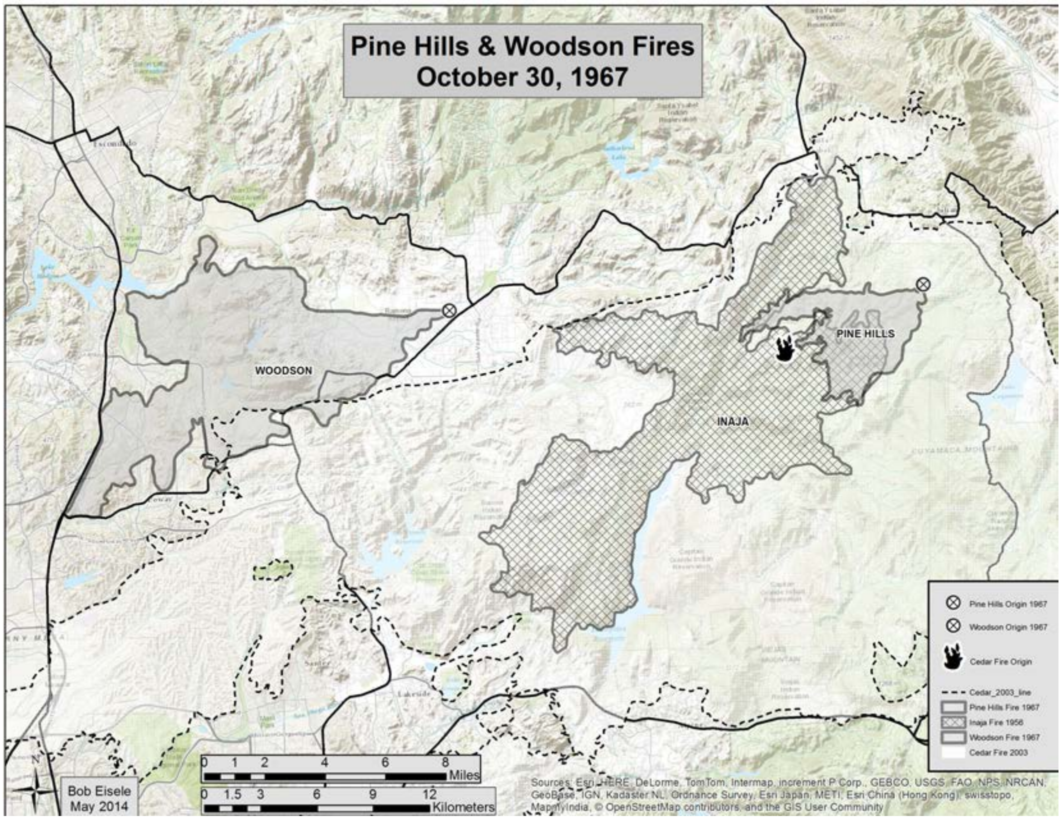

Figure 9—1967 Pine Hills and Woodson fires showing 1956 Inaja Fire.

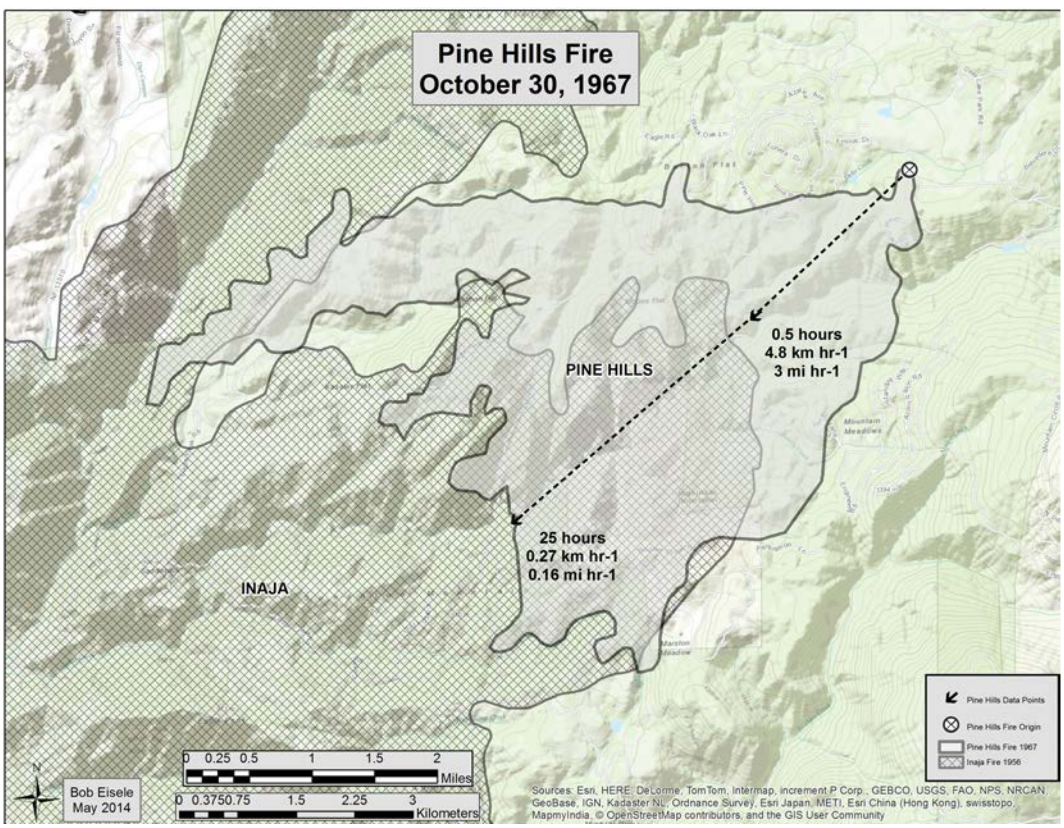

Figure 10—Estimated spread rates of the Pine Hills Fire.

Fuel age? The Pine Hills fire burned into the older Inaja Fire area of 1956. The Inaja Fire burned in 28-year-old fuels, under similar conditions, from Boulder Creek Road to Lakeside, some 22 km (14 miles) to the southwest. An aerial news photo taken on the afternoon of October 31, 1967, after the northeast winds had ended, shows the Pine Hills fire creeping downhill on southwest facing slopes of the San Diego River. The Woodson fire burned through chaparral that had last burned in 1913 (54 years previously) and stopped in 23-year old vegetation last burned in 1944.

The Cedar and Witch fires

The October 26, 2003 Cedar Fire (Figure 11) burned 110 578 ha (273 245 acres), killed 15 people, destroyed 2 232 homes and cost $27 million to extinguish (CDF. 2003). The Cedar Fire started under similar conditions and only 8 km (5 mi) from the origin of the Pine Hills Fire and 5 km (3 mi) from the Inaja Fire origin. All fuels near the origin were over 40 years old and no significant tracts of younger fuels were positioned to impede the fire's progress.

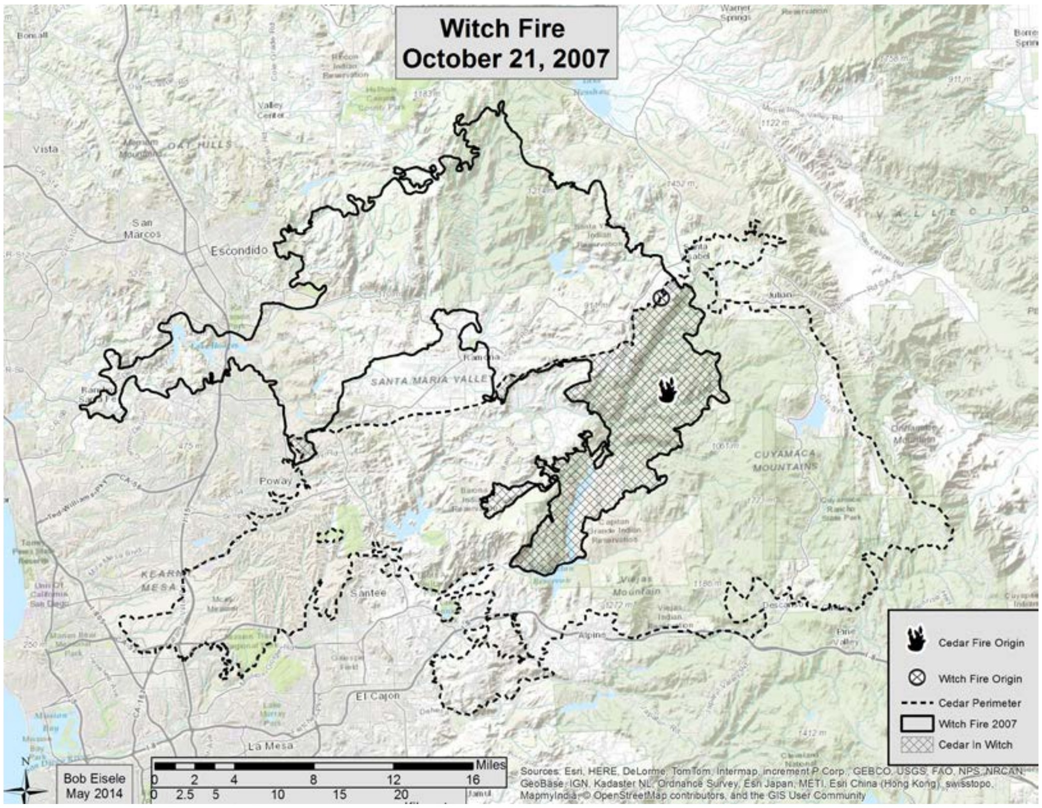

Figure 11—2007 Witch fire showing area 2003 Cedar reburn.

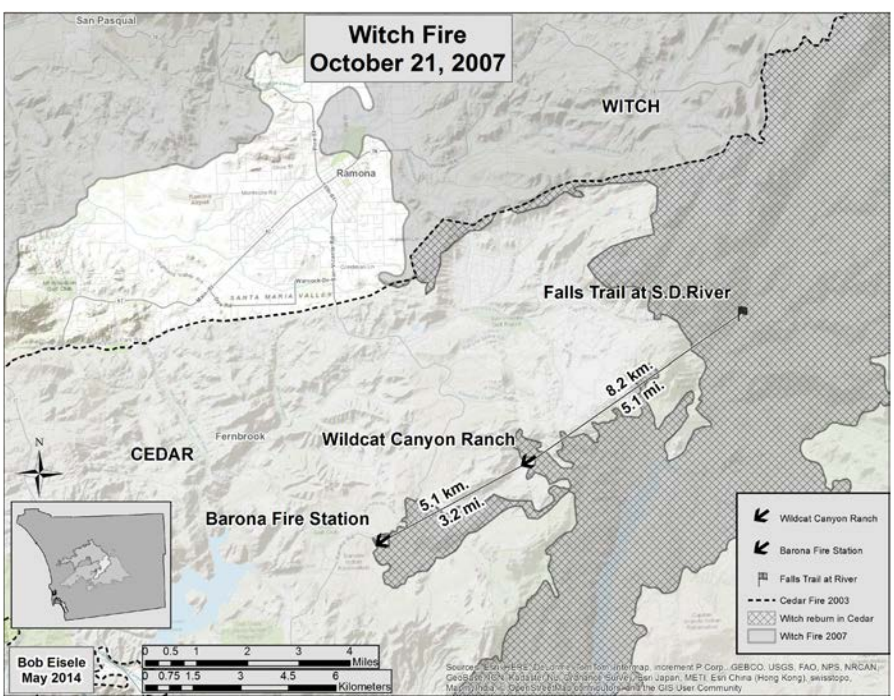

Figure 12—Spread rates of Cedar and Witch over three points.

In October of 2007 the Witch Fire (Figure 12), driven by strong north east to east winds, burned over 65 000 ha (160 000 acres) of San Diego County. 16 400 ha (40 500 acres) of the total were within the 2003 Cedar Fire (FRAP 2012). Little suppression action was taken in the four year old chaparral (Hawkins 2008). General fire arrival times were obtained at three points common to both the Cedar and Witch fires. The first point was the intersection of the Cedar Creek Falls trail with the San Diego River (Reece, personal communication). The second landmark was at the ranch house of the Wildcat Ranch on Featherstone Road (Ranch Foreman, personal communication). The third was the Barona Fire Station (Kremensky, personal communication).

The Cedar Fire traveled the 13.2 km (8.2 miles) in four hours at an average rate of 3.3 km h^{-1} (2 mi h^{-1}). The Witch Fire covered the same distance in 33 hours at an average rate of 0.4 km h^{-1} (2 mi h^{-1}). Firefighters stopped the progress of the fire at 0300 hours on October 23, 2007. At the time, the Goose Valley Remote Automatic Weather Station (RAWS) recorded air temperature of 24 °C (75 °F), relative humidity of 9%, wind from the east northeast at 8 m s^{-1} (18 mi h^{-1}), gusting to 17.4 m s^{-1} (39 mi h^{-1}). (Figure13)

Fire spread halted on the remainder of the four year old fuel portion of the Witch Fire when the wind stopped and the weather moderated. Most of the perimeter was never lined. Similar fire behavior was observed where the Witch Fire contacted the 1993 Guejito, the 1990 Paint, and the 1997 Del Dios fires.

Figure 13—Chaparral within the burned area of the Cedar and Witch fires.

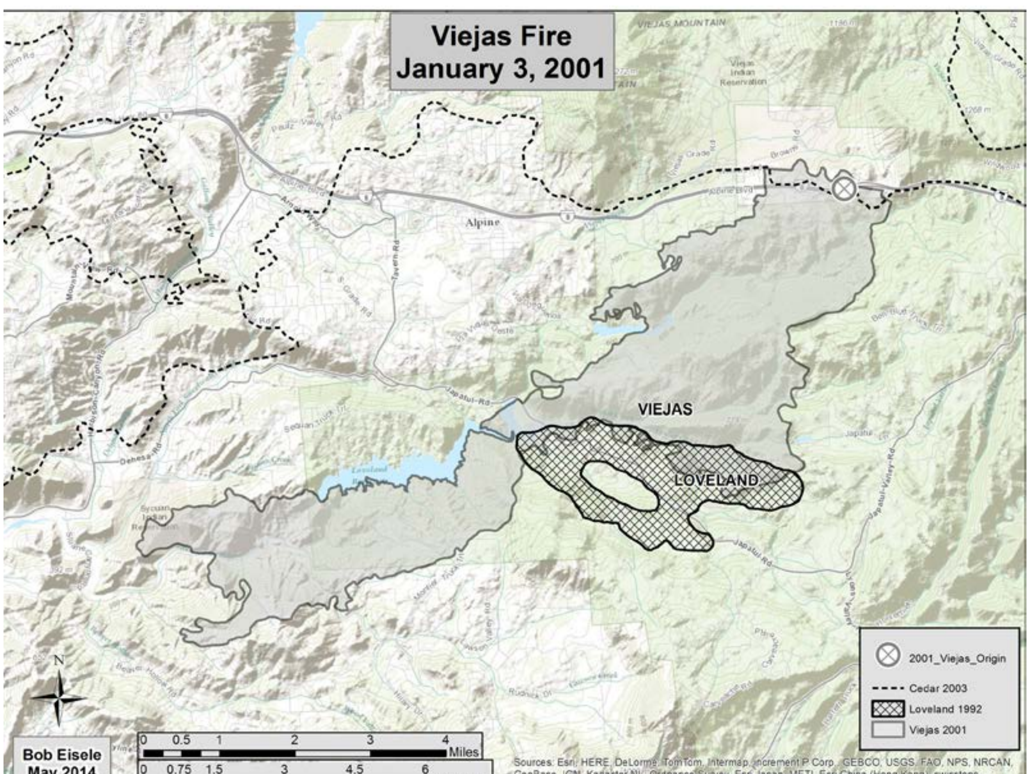

Figure 14—2001 Viejas Fire constrained by the 1992 Japatul Fire. Note 2003 Cedar constrained by Viejas (near origin).

The Viejas fire

In the early morning of January 3, 2001, the Viejas Fire (Figure 14) started in the center median of Interstate 8, about 8 km (5 mi) east of Alpine, CA. Pushed by strong Santa Ana winds, the fire skirted the eastern edge of Alpine, ran down to the Japatual Valley and climbed toward Jamul. The area had last burned in the Laguna fire of 1970 (31 years previously). The progress of the fire was slowed where it encountered the 1992 Loveland burn. Fire fighters were able to keep the fire from crossing Japatual Valley Road except west of the Loveland burn which is older fuel.

The McCoy fire

Sunday, October 21, 2007 was the first day of the 2007 “Fire Siege.” The Harris fire started at 0930 and the Witch fire began at 1230. At 2330 that night, the McCoy fire started on the west side of Cuyamaca Peak along Boulder Creek Road. Fire units responded and determined it was too dangerous to attempt suppression action due to extreme winds and darkness (Truitt, personal communication). When fire crews returned at daylight, the fire was out, having consumed 143 ha (353 acres) of young chaparral and two homes. The area had last been burned in the 2003 Cedar Fire, and the young vegetation would not carry fire, even during such extreme conditions. Recently, a newly installed weather station at Sill Hill less than 1 km (0.6 miles) from the McCoy Fire recorded a Santa Ana wind gust of (45 m s^{-1} or 101 m h^{-1}), possibly the highest gust ever recorded for San Diego County. Thus, the area of the McCoy Fire was likely to have sustained very high winds throughout the night of October 21-22, 2007.

Fire Return Interval Departure (FRID)

The calculated FRID (Eisele 2011) for San Diego County is similar to that obtained by FRID for the USDA Forest Service, Pacific Southwest Region (FRID 2012). A major difference between studies is identifying areas that have never burned or are not burnable. Some may be pastures that are annually grazed, others are agriculture lands, some are too sparsely vegetated to burn, and so forth. The basic picture is the same. Only three percent of County’s wildlands have burned more frequently than at the expected fire return interval. Fifty-six percent have burned once or not at all in the past 100 years (Table 4).

A closer inspection of the data suggests that the majority of the area that is burned frequently is associated with more flammable CSS or annual grasslands generally found at lower elevations or comprises south and west facing slopes that have a naturally shorter fire return interval (Westman 1982; Green 1981).

Fuel Age of Large Fires

The mean age of the fuel at the section of origin for fires over 4 000 ha was greater than 68.6 years. The minimum age was 26 years and the maximum was >102 years (Appendix A).

Conclusions

Two factors appear to be significant in explaining the present fire regime in the chaparral of San Diego County. First, the age of the vegetation affects the intensity and spread rate of the fire. Young fuel is receptive to suppression actions while old vegetation is very resistant to fire control efforts. An unintended consequence of fire suppression is the shifting of the fire season from moderate summertime weather to conditions with extreme foehn winds in the fall (Countryman 1974). Area burned under low and moderate intensity fires during the summer season are underrepresented in the current fire regime (Minnich and Chou 1997).

For a fire to become large there must be a successful ignition in old chaparral (greater than twenty years since last

Table 4—Fire Return Interval Departure.

Times burned	Area Burned		Percent	Category	Percent
	Hectares	Acres			Summed
0	146 148	361 127	23	Below expected interval range	56
1	208 332	514 782	33	Below expected interval range	
2	144 572	357 233	23	Within expected interval range	
3	84 914	209 820	13	Within expected interval range	42
4	36 388	89 915	6	Within expected interval range	
5	12 806	31 643	2	Above expected interval range	3
6	3 896	9 627	1	Above expected interval range	
7	780	1 928	0	Above expected interval range	
8	50	124	0	Above expected interval range	
9	6	15	0	Above expected interval range	
	637 893	1 576 212	100	Totals	

Table from: FRID. “Region 5 - Geospatial Data.” *Region 5 - Geospatial Data*.

fire), moderate to severe fire weather, and a large expanse of old vegetation ("running room") that is devoid of barriers such as younger age class fuels, urbanized areas, large lakes, deserts, oceans, and so forth. Old fuels and high winds often combine to produce fire intensities and spread rates that overwhelm the initial fire-suppression forces. "The energy of flame lines is several orders of magnitude greater than the energy expended to put them out, and this overwhelms the ability of fire fighting forces to protect property and resources" (Minnich and Sanchez-Vizcaino 1999). The fire history database is replete with examples of young age class fuels constraining fire spread, even under extreme burning conditions. This has been recognized by Philpot 1971, Hanes 1971, Countryman 1974, Biswell 1974, Green 1981, Minnich and Chou 1997, and others.

The second factor is randomness. Ignitions happen by chance. Many extreme fire days pass uneventfully, while similar periods result in multiple large fires (fire sieges). There is no statistical relationship between large fire years and drought. Spending effort on predicting fire season severity is not fruitful for chaparral. Educating the public and the policy makers on the likelihood of random rare events with very severe outcomes should be a priority. Believing that all ignitions are preventable and that large fires are inevitable are equally unsupported by science. Ignitions are random. All severe wind events are finite. Young fuels reduce the rate of fire spread, even under extreme conditions, and stop spread when weather conditions abate as during the Witch/Cedar reburn in 2003 and during the Pine Hill/Inaja reburn in 1967. If fuel management on a landscape scale is not embraced, large destructive fires are inevitable (Countryman 1974).

Perhaps a lesson can be learned from the disastrous fires that destroyed American cities in the 19^{th} and early 20^{th} centuries. The conflagration problem was not solved with more fire engines or prevention efforts– instead the fuel was modified. Wooden construction was banned in favor of fire resistant concrete and steel. (Wermiel 2000). So too, we must look to the fuels to mitigate the destructive wildland fires in San Diego.

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Appendix A. Vegetation age at origin of fires over 4 000 ha (10,000 acres) 1950-2012.

Date	Year	Name	Area (ha)	Area (acres)	Last Fire	Age	Fire Type	Cause	Fuel Type	Other
10/25/2003	2003	Cedar	109 542	270 686	1956	47	Wind-Fuel	lost hunter	chaparral	Santa Ana winds subsided after 24 hours. Remaining spread was fuel and topography driven.
9/26/1970	1970	Laguna	70 481	174 162	1910	>60	Wind	power line	forest/chap.	No Prior History
10/21/2007	2007	Witch	65 587	162 070	1910	>97	Wind	power line	mixed	Chaparral
10/21/2007	2007	Harris	36 716	90 728	1910	>97	Wind	campfire	chaparral	No Prior History
12/14/1958	1958	Stewart	27 561	68 106	1910	>48	Wind	shooting	chaparral	Started in Riverside County
7/29/2002	2002	Pines	24 965	61 691	1910	>92	Fuel	aircraft	conifers	Much of the initial area of the fire burned in 1943 (59 yrs.)
10/26/2003	2003	Paradise	22 883	56 546	1925	78	Wind-Fuel	human	sage scrub	Section has some 1996, 1925, and NFH
10/23/2007	2007	Poomacha	19 996	49 411	1910	>97	Wind	structure fire	grass	Grass-800' to NFH Chaparral
11/24/1956	1956	Inaja	18 859	46 599	1910	>46	Wind	juvenile	mixed	No Prior History
10/26/2003	2003	Otay/Mine	18 103	44 734	1910	>93	Wind	unk	scrub/chap.	No Prior History
10/30/1967	1967	Woodson	11 769	29 083	1913	54	Wind	misc.	grass/chap.	Started in grassland. Spread to 1913 chaparral
8/22/1969	1969	Walker Basin	7 896	19 513	1910	>59	Wind	unk	chaparral	Nearby fire in 1950; stopped a 1979 fire
7/16/2003	2003	Coyote	7 569	18 705	1910	>93	Fuel	lightning	chaparral	Assume county line origin - all area had no fire history.
10/27/1993	1993	Guejito	7 211	17 820	1910	>83	Wind	*powerline	chaparral	*Cause may have been compost pile
7/23/2006	2006	Horse	6 749	16 678	1970	36	fuel	human	chaparral	Laguna Fire footprint
10/22/1996	1996	Otay #322	6 702	16 562	1910	>86	Wind	campfire	chaparral	
10/18/1969	1969	San Mateo	6 376	15 757	1910	>59	Wind	flare	chaparral	No Prior History
9/28/1970	1970	Boulder	5 192	12 830	1910	>60	Wind	smoking	forest/chap.	No Prior History
10/3/1987	1987	Palomar	6 305	15 580	1919	68	Fuel	power line	groves	Origin by power line
9/22/1975	1975	Tenaja	6 047	14 942	1949	26	Fuel	misc	chaparral	1919
7/11/2011	2011	Eagle	5 662	13 993	1939	72	Fuel	structure fire	chaparral	Started at night burned into 2002 Pines fire; Grass carried the fire after
6/7/1950	1950	Case Springs	5 579	13 785	1910	>40	Fuel	misc	grass/chap.	
10/18/1989	1989	Mateo	5 455	13 479	1959	30	Fuel	unk	chaparral	Estimated. start location
7/29/1989	1989	Vail	5 454	13 478	1910	>79	Fuel	unk	chaparral	
7/22/1975	1975	San Ysidro	5 192	12 829	1910	>65	Fuel	smoking	chaparral	No Prior History
7/29/2000	2000	Pechanga	4 748	11 733	1910	>90	Fuel	unk	chaparral	Agua Tibia Wilderness
8/14/2013	2012	Wilson	4 721	11 667	1910	>102	Fuel	lightning	chaparral	Vallecito Lightning Complex -No Fire History
8/14/2013	2012	Stewart	4 302	10 630	1910	>102	Fuel	lightning	chaparral	Vallecito Lightning Complex -No Fire History
1/3/2001	2001	Viejas	4 224	10 438	1970	31	Wind	smoking	sage scrub	Laguna Fire footprint

The content of this paper reflects the views of the authors, who are responsible for the facts and accuracy of the information presented herein.