Reprint from

GEOCARTO International

Vol.19 1 2004

A Multi-disciplinary Journal of Remote Sensing & GIS

OrbView-3 Image of Sacramento , CA., U.S.A.

This 4-m resolution multispectral image was collected by OrbView-3 satellite on August 30, 2003.

The Earth From Afar: Image Review

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Southern California Fires: October 2003

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Introduction

With at least 22 deaths, an estimated one billion dollars in property damage, and nearly 750,000 acres (303,705 ha) of scourged land, the October 2003 fires in Southern California represent one of the worse disasters ever encountered in the region. These fires were captured in a set of outstanding satellite images taken by the MODIS sensors. These images provide both a temporal and synoptic view of the development and spread of the fires. This image review chronicles the October 2003 fires through these MODIS images along with some other satellite images and discusses the prospect of larger fires occurring in the future.

The MODIS (Moderate Resolution Imaging Spectroradiometer) sensor is one of several recording devices on the Terra and Aqua satellites. The Terra satellite orbits the Earth so that it crosses the equator in the morning and the Aqua satellite passes over the equator in the afternoon. Between the two satellites MODIS is able to view the entire Earth's surface every 1 to 2 days. The MODIS instrument records 36 spectral bands ranging in wavelengths from 0.4 μm to 14.4 μm and at resolutions varying from 250 m to 1 km. The images used in this review are at a 250 m resolution. MODIS images play a key role in the development of global models of Earth systems.

Every day the MODIS web site introduces a new image. The images presented in this review can be downloaded from this site by doing a search on the key words "California" and "fires." The site's URL is:

http://modis.gsfc.nasa.gov/gallery/index.php#

October 2003 Fires

By late October 2003, Southern California was experiencing several large fires. On October 23, the MODIS scanner on the Aqua satellite recorded the image shown by Figure 1-A. The large smoke plumes were associated with the Grand Prix Fire (east of Los Angeles) and the Roblar 2 Fire (south of Los Angeles). Based on the clouds and smoke plumes the prevailing westerly winds were pushing the smoke eastward. However, conditions were developing to produce the Santa Ana winds that would shift the fires and smoke westward toward the big cities of Southern California.

On October 25, the Aqua's MODIS scanner captured its second image of the Southern California fires, which is shown in Figure 1-B. A huge wildfire was burning east of Los Angeles near San Bernardino. The Santa Ana winds were in effect as illustrated by the large smoke plumes flowing west and southwest. The interior deserts were clear of any clouds indicating the existence of a high-pressure condition. This high-pressure was fueling the strong Santa Ana winds. The Grand Prix Fire continued to burn, and to the east of it, the area called the Old Fire was burning. A smaller wildfire, Piru, was ablaze northwest of the city. The Grand Prix Fire forced the closure of two major highways and the evacuation of thousands of residents east of Los Angeles. Triple-digit temperatures and gusty Santa Ana winds made fighting the fires almost impossible. Thousands of acres in the San Bernadino National Forest were already burned.

On Sunday, October 26, ASTER, another sensor on the Terra satellite, recorded the image displayed in Figure 2. The image shows the Old Fire/Grand Prix Fire burning on either side of Interstate 15 near the Cajon Pass in the San Bernardino Mountains 50 miles (80 km.) east of Los Angeles. At this point in time this fire had burned over 80,000 acres, (32,400 ha.) consumed 450 structures, and caused 2 fatalities. Local communities were evacuated as the fire continued to

Geocarto International, Vol. 19, No. 1, March 2004
Published by Geocarto International Centre, G.P.O. Box 4122, Hong Kong.
E-mail: geocarto@geocarto.com
Website: http://www.geocarto.com

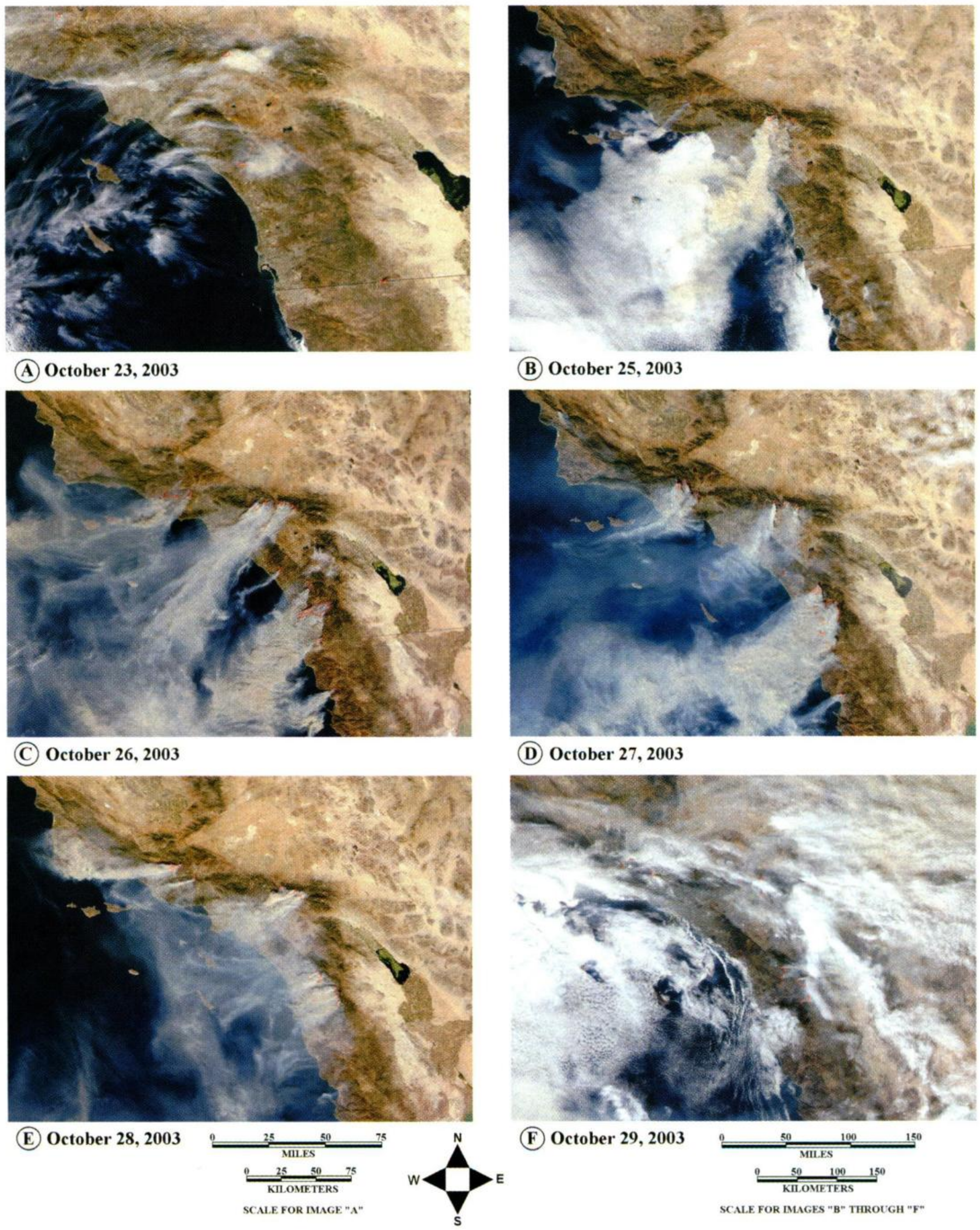

Figure 1 MODIS images of Southern California from October 23 to October 29, 2003. Images prepared by MODIS Land Rapid Response Team, NASA GSFC.

spread. Below the smoke in Figure 2 are San Bernardino and other suburban cities.

Also on October 26, a huge fire broke out east of San Diego and smoke overshadowed the city. This was the massive Cedar Fire, which is visible on Figures 1-C, 1-D, and 1-E. The smoke became such a problem by October 27 that the Monday night football game between the San Diego Chargers and the Miami Dolphins had to be moved at the last moment to Phoenix. The movement of this game brought to the attention of many Americans just how severe the California fires had become.

Also on October 27, the QuickBird satellite recorded the Grand Prix Fire. Figure 3-A shows a small portion of the QuickBird image. At a 60 cm picture resolution the fires can easily be seen approaching the small community of Lythe Creek, which is located in the San Gabriel Mountain Range, 20 miles (32 km.) northwest of San Bernardino. The heat from the fires overloaded the sensor, creating artificial looking flames. Under these conditions a solid red color appears with no differentiation within the flames. When the winter rains arrive in November, people in this valley will be watching the burnt hillside slopes for mudslides. (Note that the top of

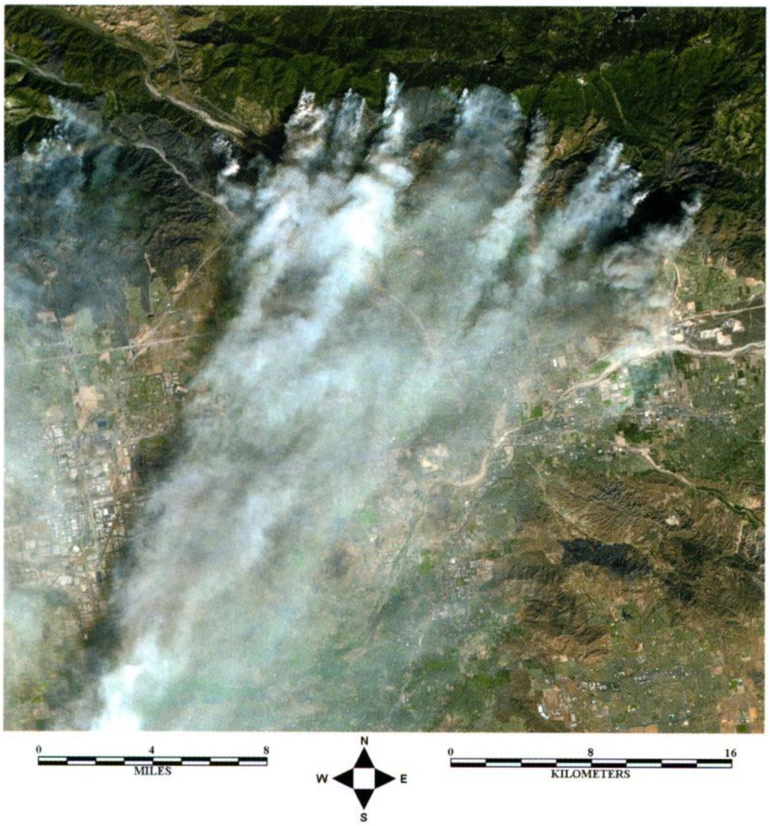

Figure 2 Smoke blankets San Bernardino, California on Sunday, October 26. ASTER image prepared by NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.

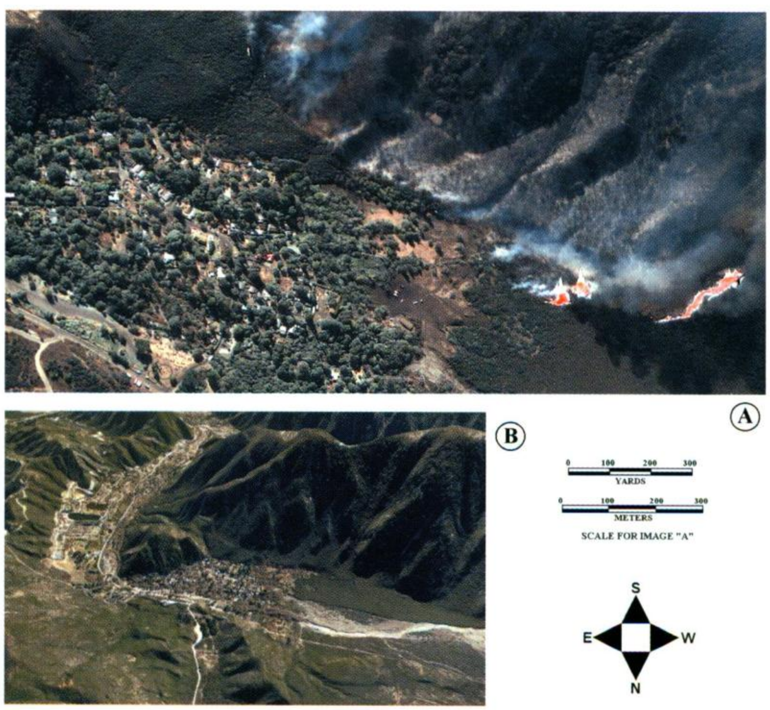

Figure 3 Community of Lythe Creek facing fires on October 27. Image from DigitalGlobe's QuickBird satellite. The three dimensional perspective is from Earthviewer.

the image is south.) Figure 3-B, a three-dimensional perspective of the Lythe Creek area, illustrates the surrounding slope conditions. The relative relief is around 1700 feet (518 m).

By October 27, the wildfires started to merge forming walls of flame stretching for miles. Firestorms developed from fierce Santa Ana winds, with near-hurricane gusts of up to 70 miles per hour (112 km. per hour). One fire burned 10,000 acres (4050 ha.) in just 6 hours. Air travel from Southern California was disrupted, which in turn, impacted other flights across North America.

Conditions did not improve on October 28. As shown on Figure 1-E, heavy smoke covered the Southern California coastal communities as multiple fires continued to burn and the Santa Ana winds pushed the fires westward. The clear skies over the interior deserts indicated that a strong high pressure still existed, feeding the strong Santa Ana winds. The Old and Grand Prix Fires near San Bernardino persisted and the Cedar and Paradise Fires just on the outskirts of San Diego remained out of control. Although many fires existed, these four fires dominated the region. Table 1 demonstrates the amount of damage from these four fires. The Cedar Fire was the largest single blaze fire ever recorded in California, eclipsing the 1932 record of 220,000 acres (89,100 ha.).

On October 29, the prevailing westerly winds started to return, shifting the smoke from the fires northeastward over Nevada and western Arizona. Figure 1-F shows the smoke and clouds over the interior deserts. These winds were calmer and forced the fires to move back over the already burnt areas. With the lack of fuel to burn the fires could now be controlled by the nearly 12,000 firefighters who had been combating the fires for nearly a week.

Figure 4 is a false-color Terra MODIS image taken on November 18, 2003. It illustrates the amount of land burnt by the October wildfires and the close proximity of these fires to the region's large urban areas. Healthy vegetation appears as bright green, burnt areas as dark red, bare land as pink, and the cities as light gray. The Piru, Simi Incident, and Verdale burn scars can be seen northwest of Los Angles. The burn scar made by the Old, Grand Prix, and the Mountain Fires are directly east of Los Angeles on the outskirts of San Bernardino. The most extensive burn scars are from the Paradise and Cedar Fires just east of San Diego. The Otay Fire scars appear on the border of

Table 1 Fire Damage and Deaths

	Old Fire	Cedar Fire	Grand Prix Fire	Paradise Fire
Acres Burnt	91,281	273,246	59,448	56,700
Hectares Burnt	36,969	110,665	24,076	22,680
Deaths	6	14	0	2
Injuries	12	113	35	24
Homes Destroyed	933	2,232	135	221
Other Structures Destroyed	10	588	70	192

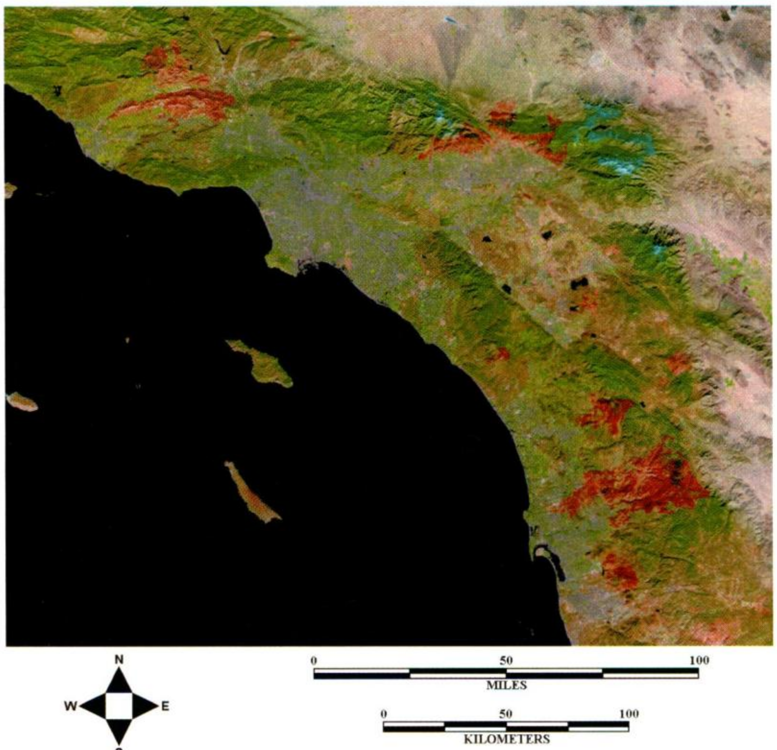

Figure 4 Burn scars in southern California. Image prepared by Jeff Schmaltz, MODIS Rapid Response Team, NASA/GSFC.

California and Mexico just outside of Tijuana. Close examination of this image shows how the fires extended into the suburban areas.

On October 31 a Terra MODIS image captured a pale gray haze over the Bay of Fundy, between Maine and Nova Scotia. This haze most likely came from the fires in Southern California, which illustrates how fires of this magnitude can become global in their impact.

Future Fires

Being situated within a climatic realm that has a distinct long dry summer period, Southern California faces a fire season every September and October followed by a mudslide period when the winter rains arrive. California, like southern Europe, central Chile, the southern tip of South Africa, and two locations in southern Australia, falls into a climatic realm referred to as the Mediterranean climate. The major characteristics of this climate are warm, dry summers and mild, wet winters. During the summer period these regions receive winds flowing eastward from subtropical high-pressure cells situated just off the coast over the ocean. Being so close to the coast these winds, called *westerlies* (based on their origin point), have little opportunity to collect water vapor from the ocean before crossing the land. In fact, this situation results in little, if any, precipitation during the summer. The amount of precipitation resembles desert conditions. With the migration of the global circulation system, the subtropical high-pressure cells shift farther away from the Mediterranean climatic regions during the winter months. This shift allows the westerlies to gather more moisture as they cross over the oceans, which results in more precipitation. Figure 5 shows the precipitation pattern for Los Angeles, which is typical of most Mediterranean weather stations.

In addition to the influence of the subtropical high-pressure cells on the precipitation condition over Southern California, the basically north-south orientated mountains of the region create *orographic* barriers. These barriers force the westerlies to move over them, and in the process, more precipitation falls on the west side of the mountains than on the east side. This situation creates a desert climatic realm in the interior portion of Southern California. Thus, the coastal area of Southern California is mainly a semi-arid Mediterranean realm and the interior an arid region. Figure 6 shows the coastal and desert counties.

During the winter months high pressure conditions can develop over the interior deserts resulting in strong, gusty winds flowing westward down into the coastal sections of Southern California. These are the Santa Ana winds. Averaging 40 miles per hour (64 km. per hour) as they descend down the pressure gradient between the interior and coastal areas, these winds are dusty, hot, and dry and continue out to sea as far as 100 miles (161 km.) offshore. They can create relative humidity conditions as low as 5 percent and draw out what little moisture is left in the vegetation after a dry summer. Santa Ana winds commonly occur between October and February with December having the highest frequency of these events. These winds are particularly devastating during the fire season when they can push fires rapidly toward the built up sections of Southern California. As illustrated by the MODIS images the Santa Ana winds played a major role during the October 2003 fire season.

Several other conditions primed the landscape for the October 2003 fires. The four-year-old drought throughout Southwest United States and the ravaging of trees by bark beetles

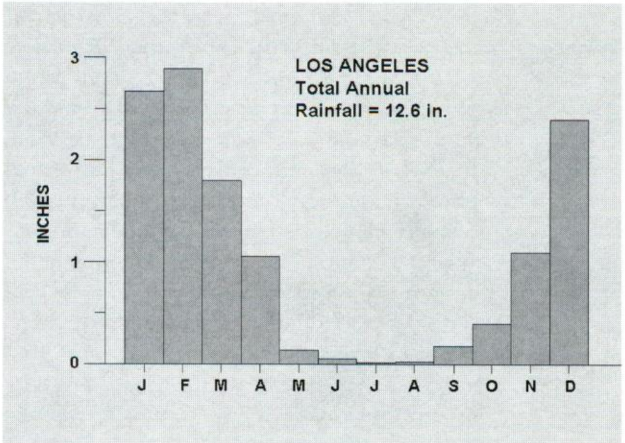

Figure 5 Precipitation Chart of Los Angeles, California.

resulted in large accumulations of dead material in the forests. Also, decades of fire suppression had created forests with very high densities of bush-like trees; the normal forests in this climatic realm have more open space and larger trees. These conditions combined with the Santa Ana winds created fast-moving crown fires.

However, due to conditions not apparent to many people the October 2003 fires might be a prelude to bigger and more devastating fires. Studies show that urban areas are warmer than comparable rural environments by 0.9 to 5.4°F (.5 to 3.0°C). This situation is due to high population densities and urban land uses (Landsberg, 1981). With respect to the coastal areas of Southern California these warmer conditions produce low-pressure cells over the cities. As the urban landscapes increase, even warmer temperatures will occur in the cities, which will most likely result in the development of stronger low-pressure cells. With stronger low-pressure conditions, steeper pressure gradients will materialize in conjunction with the winter high-pressure areas over the interior deserts. Steeper pressure gradients can produce stronger Santa Ana winds and more such winds. These winds can bring about more fires and push the fires into the populated areas of Southern California.

At the present time the population of the five coastal counties (Los Angles, Orange, San Diego, Santa Barbara, and Ventura) of Southern California is 16,636,800. In comparison to U.S. states, only California (in its entirety), Texas, New York and Florida have larger populations. The overall population density of this area is around 1,213 people per square mile (3,142 people per sq. km.). However, mountains occupy large portions of the coastal counties and these areas have low densities. The flat coastal plains and valleys have densities exceeding 4,000 people per square mile (10,360 per sq. km.). Using figures prepared by the Demographic Research Unit of the State of California's Department of Finance, population estimates were generated for every five years between 2000 and 2100. Figure 7 illustrates in graph form the population growth of this region

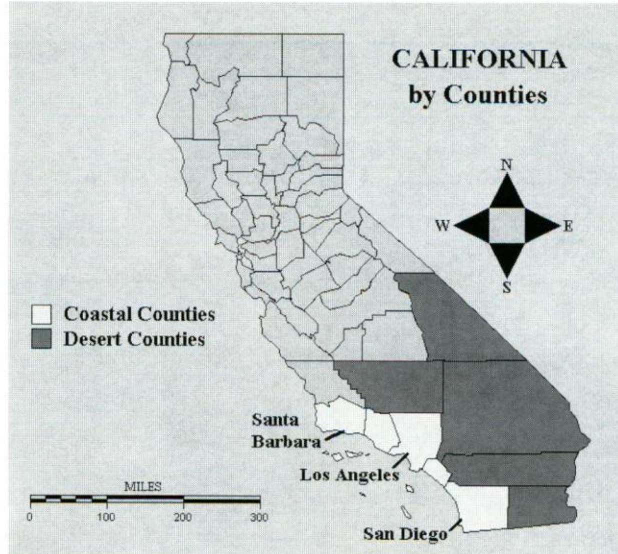

Figure 6 Map of California showing the coastal and interior desert counties.

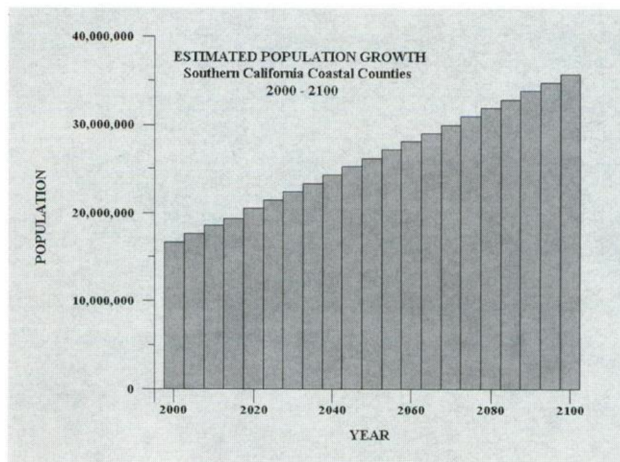

Figure 7 Population Chart for 2000 to 2100 of the coastal counties in Southern California.

over the next 100 years. By 2100, the coastal counties will have an estimated combined population of 35,768,400. This population will create a much higher density of people and urban land use, and this condition, in turn, will result in higher temperatures and stronger low pressures, the building blocks for stronger Santa Ana winds and potentially worse fires.

References

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