Fire Predictions for Southern California

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Abstract:

Southern California wildfires are increasingly destructive and it is widely held that the problem has been intensified by many climate factors including vegetation types, precipitation, temperature, wind properties, and elevation. Southern California must take precautionary methods to predict future fires to further prepare for any outbreaks. By analyzing San Diego County fires and the multiple attributes of the area, future fires in the Southern California region can be predicted based on the dynamics of the area. Using ArcMap, previous studies, and available spatial data, these fires can be forecasted, and preventive measures can be taken.

Introduction:

On October 20th of 2007 a series of wildfires began burning across Southern California. Over the week, at least 1,500 homes were destroyed, over 500,000 acres of land burned from Santa Barbara County to the U.S.–Mexico border, and nine people died as a direct result of the fire; 85 others were injured (Perry).

The major contributing factors to these fire conditions include the extreme drought during 2006-2007, which is the driest year on record after rainfall just a fifth of average levels (Diaz). The brush was also abundant after growth in previous years with more moisture, such as the extremely moist year of 2004, just after the 1998-2002 drought and the last major fire incidences in Southern California in 2003. Other conditions that made these fires possible included the hot weather and the strong Santa Ana winds with gusts up to 85mph (Perry).

Due to the destructive force of fires it is essential that fire fighters, government officials, and local residents understand when and where possible fires can ignite and spread so they are better prepared to protect the population against them. Here we address the necessity of increased fire-protection and prevention in relation to naturally-caused fires by looking at what conditions are optimal for fires to occur in Southern California. We analyzed data from the San Diego fires that occurred in 2007: Ammo, Harris, Poomacha, Rice and Witch.

The environmental factors we hypothesized would affect the frequency of fires in the area include vegetation, precipitation, wind velocity, elevation, and regional temperature.

Methods:

Study Area:

We focused our analysis on the five fires that occurred in San Diego County and then compared all of our results to where in Southern California fire conditions exist, and thus where future fires may ignite and spread.

Data Sources:

Elevation for San Diego County was found at: http:\\seamless.usgs.gov

Basemap Data from Professor Soeller's files:
https://webfiles.uci.edu/xythoswfs/webui/_xy-5133325_1-t_TkxF0vKp

Elevation for Southern California found at: https://eee.uci.edu/08w/42130/classfiles

Vegetation data found at: www.biogeog.ucsb.edu/projects/gap/gap_home.html

Precipitation shapefile found at:
http://www.sandag.org/resources/maps_and_gis/gis_downloads/senlu.asp

Precipitation data found at: http://www.wrh.noaa.gov/cnrfc/versprod.php?pil=RR4&sid=RSA&version=0

Fire data found at Professor Soeller's webfiles (no link)

Wind Data found at: http://www.prh.noaa.gov/regsci/gis/shapefiles/ndfd/

ArcMap Procedures used:

For each map we clipped the features to San Diego County, then we applied the fire perimeter layers and eliminated all but the fires that occurred in San Diego County. We used the append command to put all five fires onto one shapefile. We joined the vegetation and fire layers to find which vegetations occurred in each fire, we then used the field calculator to remove all but the six vegetation types that burned in three or more fires to evaluate which vegetation types could possibly ignite to create future fires. We used the same procedure to evaluate precipitation and wind data, finding the possible areas of a fire breakout. For elevation, the elevation raster file was converted to a contour shapefile with a base contour of 100 meters and a contour interval of 100 meters. Clipping that shapefile to the shapfile of the fire areas resulted in the elevation range in which the fires occurred. After our analysis on San Diego County, we applied all of the features to the Southern California Counties, and checked for common properties of the fire perimeters in San Diego.

Results:

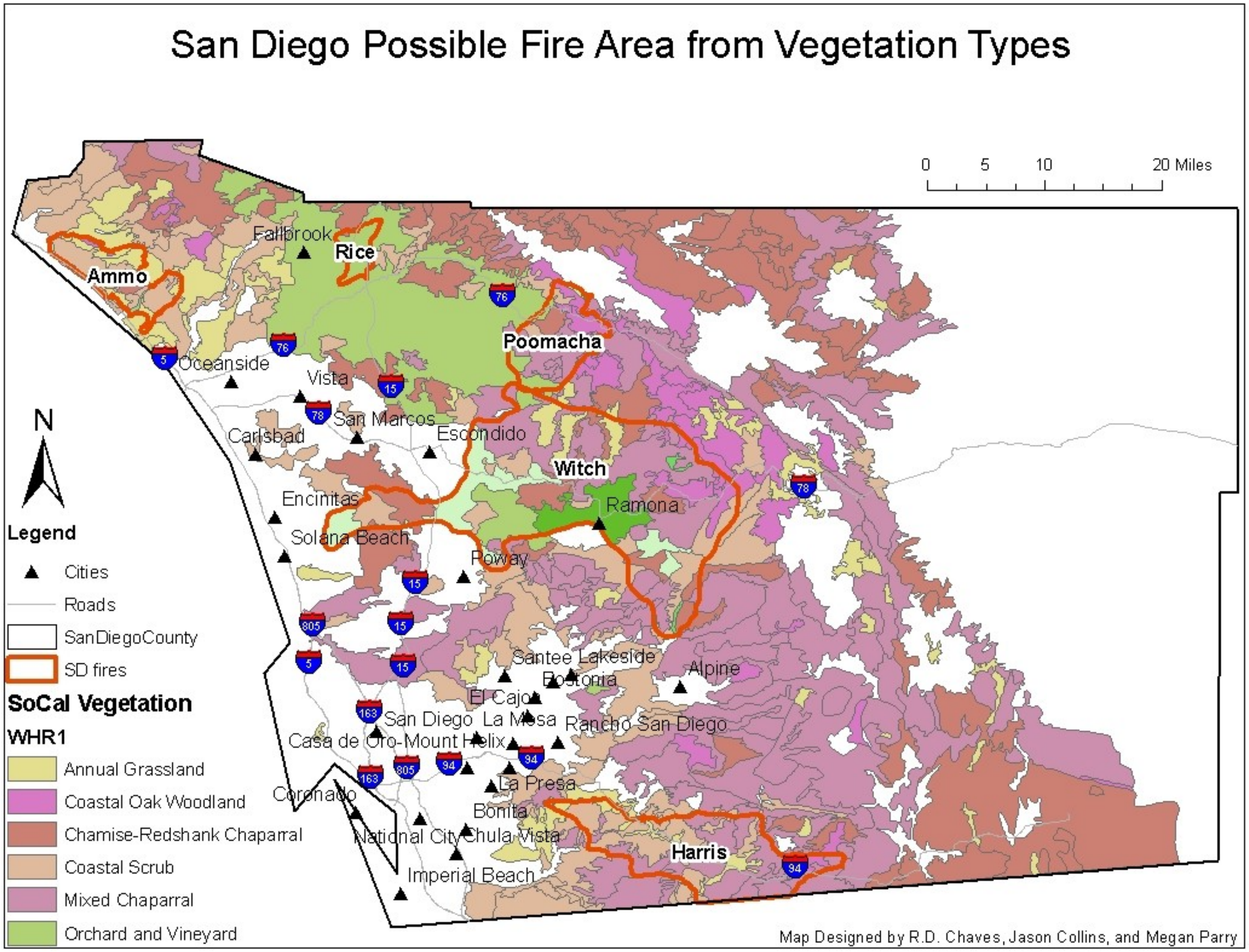
When looking at vegetation we found a vast amount of different vegetation types, so we narrowed it down to which ones were burned in multiple fires and found the following results:

Fire	Vegetation Type
Rice	CRC, OVN, CSC
Ammo	CSC, AGS, CRC, VRI, COW, URB
Harris	AGS, CSC, MCH, COW
Witch	URB, CSC, CRC, OVN, MCH, COW, LAC, AGS
Poomacha	OVN, MCH, COW, SMC, CSC

Code	Vegetation Name	No. Fires
AGS	Annual Grassland	3
COW	Coastal Oak Woodland	4
CRC	Chamise-redshank chaparral	3
CRP	Cropland	
CSC	Coastal Scrub	5
LAC	Lacustrine	
MCH	Mixed Chaparral	3
MHW	Montane Hardwood	
OVN	Orchard and Vineyard	3
SMC	Sierran Mixed Conifer	
URB	Urban	
VRI	Valley-Foothill Riparian	

Since there are only six vegetations types that burned in three or more fires we concluded that those are the six most likely vegetation types to catch fire in the future. Below is a map displaying all the areas in San Diego County where future fires could occur based on vegetation type (Figure 1). The blank area on the right side of the map represents mountains, including the San Miguel Mountains, and desert area.

Fig 1


San Diego Possible Fire Area from Vegetation Types
0 5 10 20 Miles
Fallbrook
Rice
Ammo
Poomacha
Oceanside
Vista
San Marcos
Carlsbad
Escondido
Witch
Encinitas
Ramona
Solana Beach
Poway
Santee
Lakeside
Bostonia
Alpine
El Cajon
San Diego
La Mesa
Rancho San Diego
Casa de Oro-Mount Helix
La Presa
Coronado
Bonita
National City
Chula Vista
Harris
Imperial Beach
N
Legend
Cities
Roads
SanDiegoCounty
SD fires
SoCal Vegetation
WHR1
Annual Grassland
Coastal Oak Woodland
Chamise-Redshank Chaparral
Coastal Scrub
Mixed Chaparral
Orchard and Vineyard
Map Designed by R.D. Chaves, Jason Collins, and Megan Parry

The next condition we looked at was precipitation, however we had trouble finding data for the 2007 year, the closest we could find was from 1994, and after doing research to determine if this year could be used we learned that 1994 was a fairly dry year, with less than 12 inches of rainfall. While this doesn't fit exactly with the 2007 year, which had less than 5 inches of rainfall, it does provide us with locations of low rainfall for the 1994 year which we are going to assume correlates to low rainfall in 2007. We understand this is a fairly large assumption, but we believe it is necessary in order to estimate future fire predictions for precipitation. Since we were unable to find the 2007 precipitation shapefile we have provided the table below which shows the extremely low rainfall levels of 2007 compared to the normal.

CLIMATE STATION	Jul 01-12-Mar 2008	PON	Jul 01-12-Mar 2007	PON	Jul 01-12-Mar Normal	Jul 01-30-Jun Normal
SAN DIEGO - LINDBERGH	6.74	80	3.3	39	8.43	10.77

PON is the percent of normal for the period
Normals are 1971-2000 averages
From the National Weather Service website

From the table we see that the San Diego precipitation levels were 39% of the normal, creating dry conditions which allow for wildfires to spread quickly once started. Although we couldn't find a shapefile for the 2007 precipitation, we were able to find the image below from NOAA for precipitation during the time of the fires in October of 2007 (Fig 2).

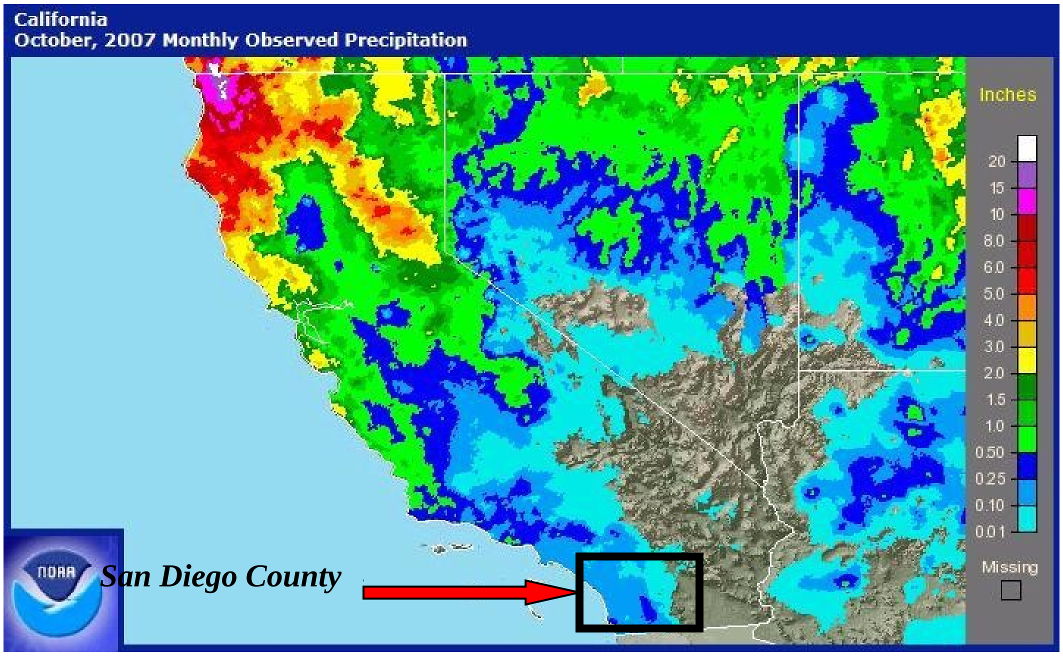
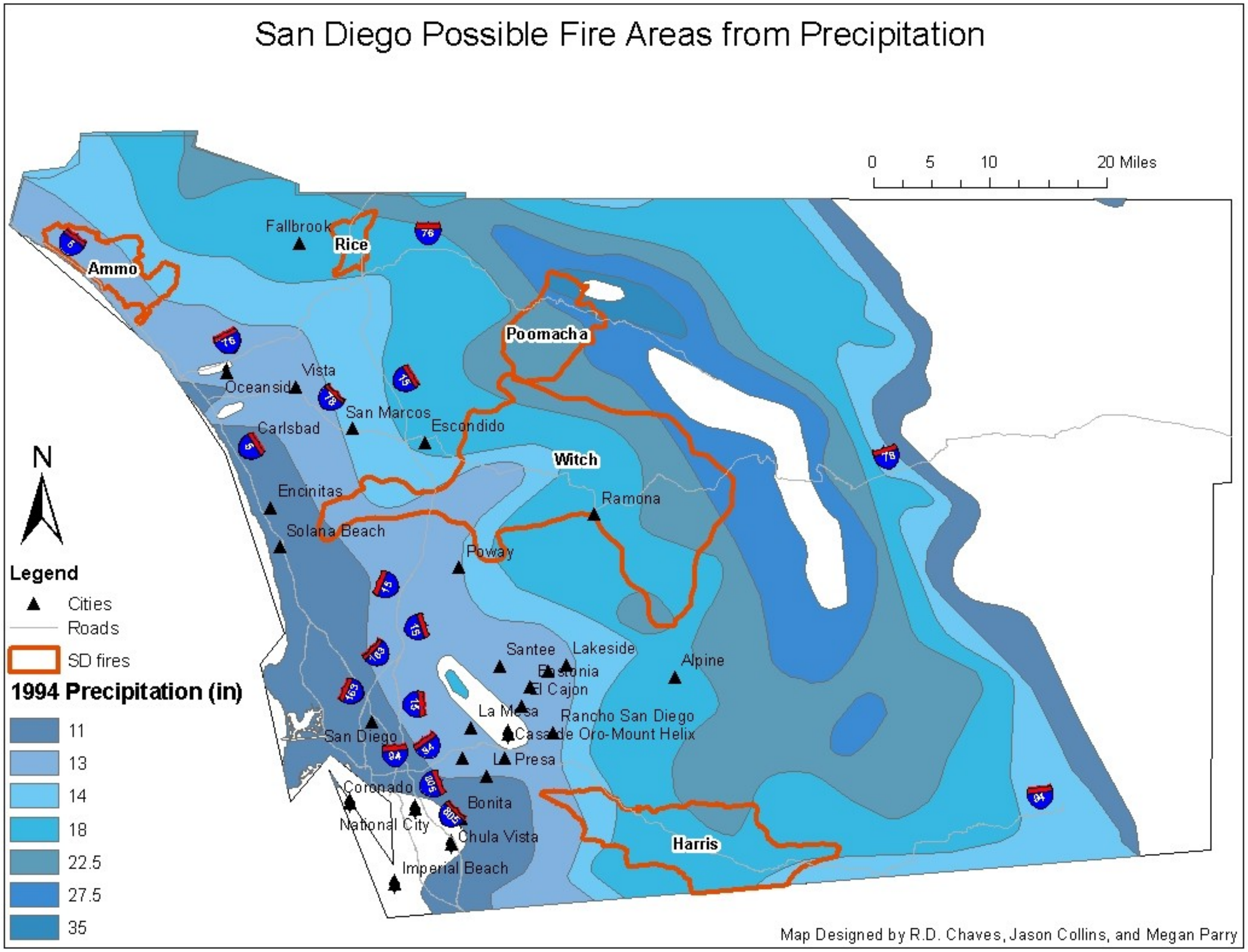


Figure 2

From this we can see that the lowest moisture levels were in San Diego County between 0.01 and 0.25 inches. Over the 2007 year precipitation had been low which continued into October creating dry vegetation which can quickly ignite, and with the strong Santa Ana winds can spread a fire even quicker. Below is our graph of the 1994 precipitation data, although the precipitation is higher than it was in 2007, our assumption that the regions of low precipitation where the fires occurred would stay the same lead us to believe that the following regions would be prime areas for future wildfires in San Diego County (Fig 3).

Fig 3


San Diego Possible Fire Areas from Precipitation
0
5
10
20 Miles
Fallbrook
Rice
Ammo
Poomacha
Witch
Harris
Vista
Oceanside
San Marcos
Escondido
Carlsbad
Encinitas
Solana Beach
Poway
Ramona
Santee
Lakeside
El Cajon
Alpine
La Mesa
Rancho San Diego
Casa de Oro-Mount Helix
San Diego
La Presa
Coronado
Bonita
National City
Chula Vista
Imperial Beach
N
Legend
Cities
Roads
SD fires
1994 Precipitation (in)
11
13
14
18
22.5
27.5
35
Map Designed by R.D. Chaves, Jason Collins, and Megan Parry

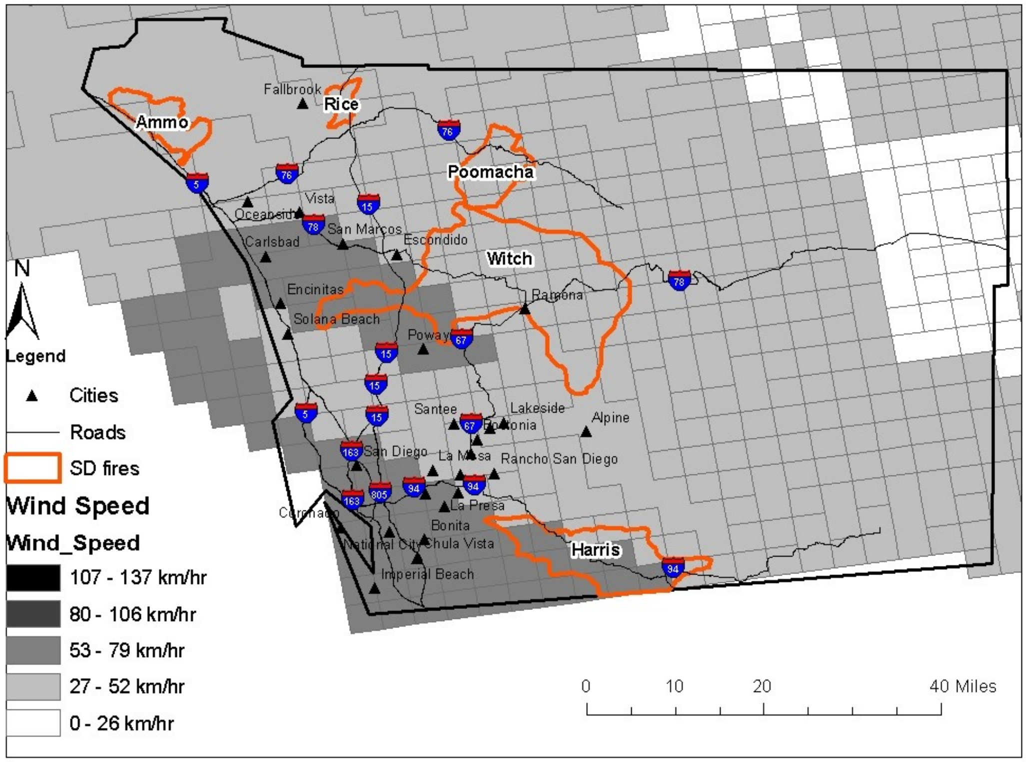
The third condition we looked at was wind direction and wind speed. Generally, the fire locations in San Diego share a commonality of wind direction and speed. Wind direction and speed can increase the energy of the fire, spreading the fire's perimeter. Depending on the speed of the wind, a fire can double in size quickly. This factor is most apparent in the Witch and Harris fires, which were the two bigger fires in San Diego County. An increased wind speed is one of the main factors in the increased perimeter size of the fire locations.

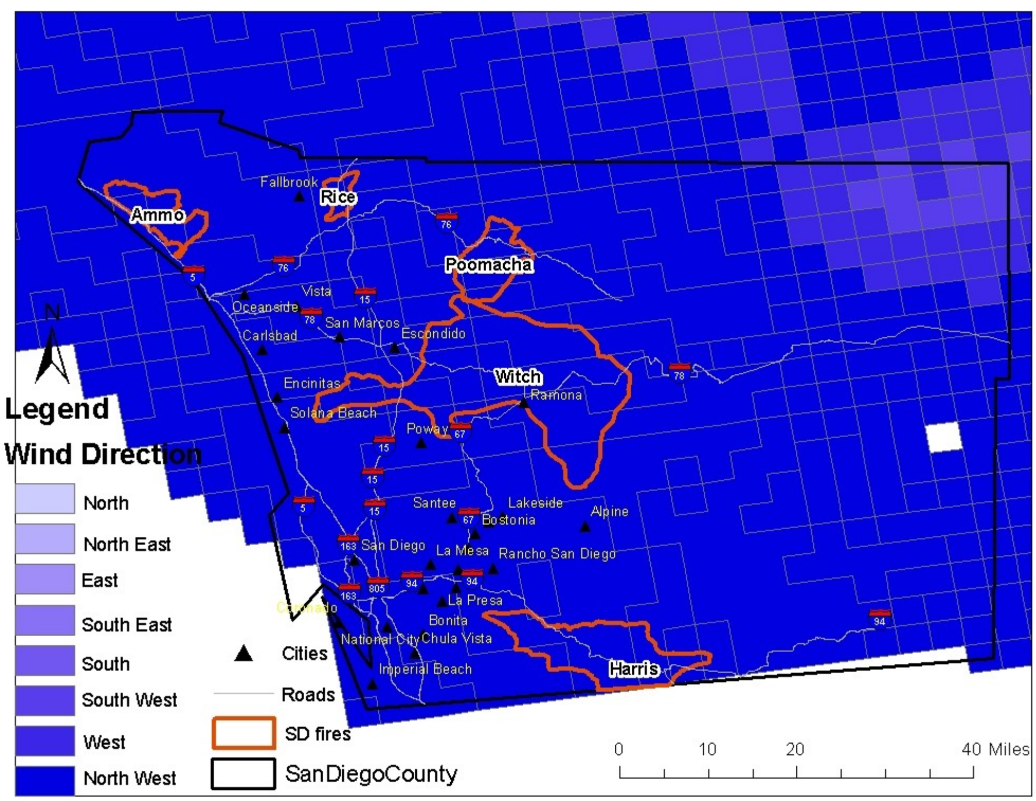
The presence of Santa Ana winds is a major factor in all Southern California fires. A warm easterly wind creates a temperate dry environment, generating a potentially dangerous setting for a fire. The Santa Anas develop when high pressure builds over the Great Basin, and the cold air there begins to sink. As the wind's temperature rises, the relative humidity drops; the air starts out dry and winds up at sea level much drier still. The air picks up speed as it is channeled through passes and canyons. These fast, hot winds cause vegetation to dry out, increasing the danger of wildfire. Once the fires start, the winds fan the flames and hasten their spread.

The combination of wind, heat, and dryness accompanying the Santa Ana winds turns the chaparral and other types of vegetation into fuel feeding the wildfires for which the Southern California region is known for. The image below shows the typical wind speed and direction in San Diego County during a typical Santa Ana Event (Fig. 4). Considering Santa Ana events as a temporal and spatial condition, future fire locations can be derived from our other conditions and the probability of a fire will be greatly enhanced.

Fig 4

San Diego Possible Fire Area from Wind Speed and Direction





Map Designed by R.D. Chaves, Jason Collins, and Megan Parry

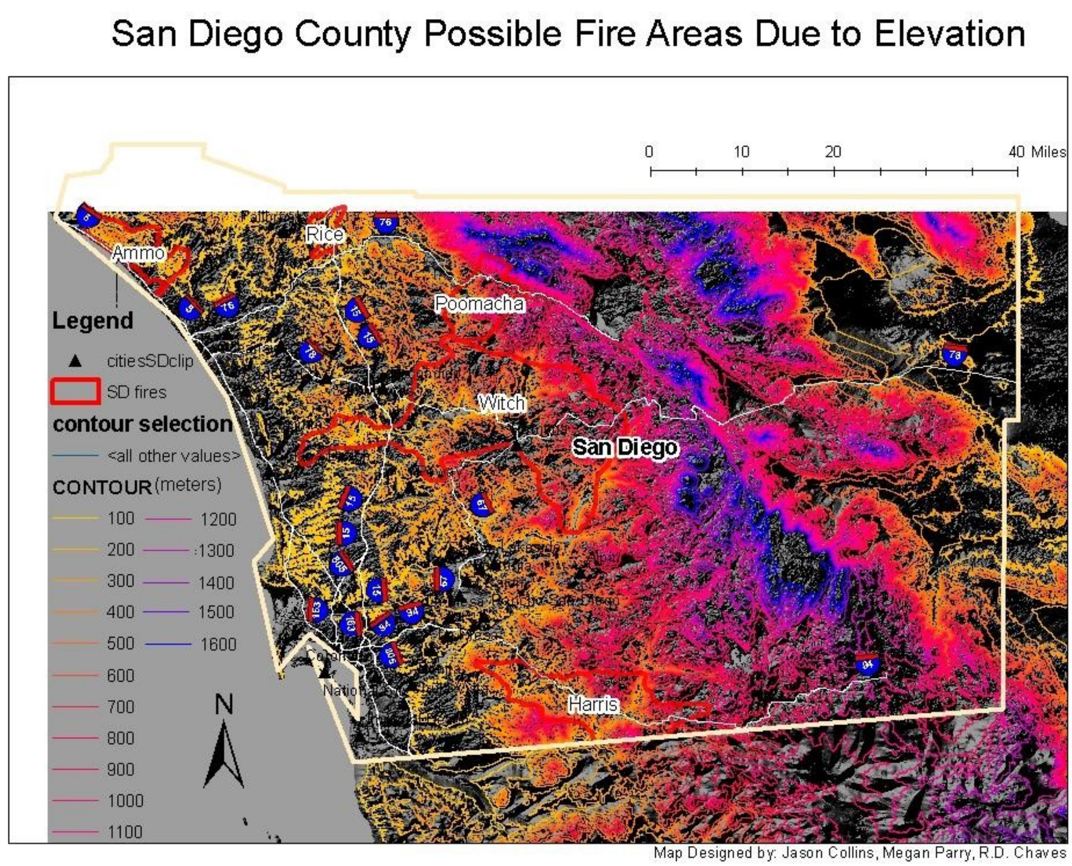
We then looked at temperature during the month of October, but we were unable to find a shapefile displaying the temperature, so we researched the information instead. According to information provided by NOAA, “in the contiguous United States, the average temperature for October was 56.9°F, which was 2.1°F above the 20th century mean, making it the ninth warmest October on record, based on preliminary data” (Climate). Below is a chart showing the average temperatures of San Diego County during the week of the fires in October. While the initial days of the first fires aren’t that different then past years, the periods when the fires were strongest, the 22nd – 25th, the temperatures were much higher than the average mean temperatures. These figures represent that the fire has a strong manipulation over the average temperature, measured at any given station. Generally speaking, drier areas with higher temperatures are always more susceptible to fires.

Month	Day	Year	Mean Temp (F°)	Year	Mean Temp (F°)	Year	Mean Temp (F°)
10	20	**1995**	64.3	**2006**	68.3	**2007**	65.1
10	21	**1995**	66	**2006**	66.5	**2007**	66.3
10	22	**1995**	64.8	**2006**	66.8	**2007**	72.3
10	23	**1995**	64.3	**2006**	67.1	**2007**	72.3
10	24	**1995**	63.8	**2006**	65.5	**2007**	74.2
10	25	**1995**	63.8	**2006**	64.3	**2007**	71.9
10	26	**1995**	62.8	**2006**	66.1	**2007**	63.8
10	27	**1995**	64.8	**2006**	67.2	**2007**	64.7

The final condition we looked at for possible fire areas was elevation. Analyzing these areas, a wide range of elevation was burned in the fire areas. Within the five fire areas, elevation between sea level and 1600 meters was burned. Because such a wide range of elevation heights were burned, it seems that no strong cause-and-effect relationship can be determined between initial fire conditions and elevation, except that fires do not start above 1600 meters.

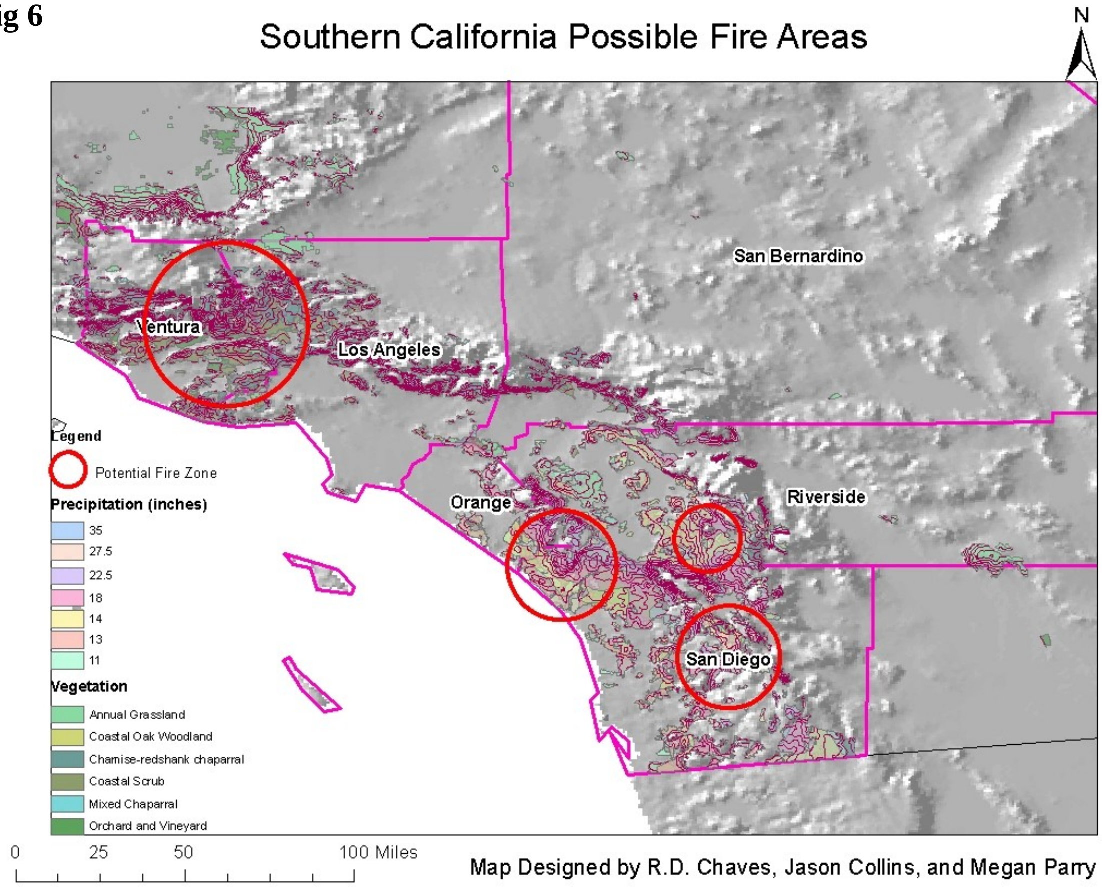
The figure below shows the contour lines in San Diego County that occur within the range of elevations burned by the five San Diego fires (Figure 5). Labeled by color for elevation height, it shows that a majority of San Diego County falls within the elevation range.

Fig 5



Discussion:

Fig 6



Our final analysis was on the image above which includes all areas prone to fire based on vegetation, precipitation, and elevation; wind speed was not included because the areas above are the ones prone to fire and Santa Ana winds enhance the likely hood that fires will occur in these areas (Figure 6). Not all aspects analyzed solely contribute to the fires in San Diego County. Applying the many characteristics shared among San Diego County fires, in particular the October 2007 fires, to the rest of Southern California produced a vast expanse of potential fire danger zones. Susceptible vegetation in the San Diego County, Orange County, Los Angeles County, Ventura County, and San Bernardino County, below seventeen-hundred meters, is at potential risk during the dry season especially when Santa Ana winds are prevalent. Our study follows the trends that other Fire Protection Agencies follow as well.

Combined with the data of California Fire and Resource Assessment Program (FRAP), this project shares many commonalities with their analysis. The high threat areas produced from their studies coincide with our dry vegetation and wind data. The areas of biggest concern are of dry vegetation and during increased easterly winds. FRAP uses the same technique in determining potential fire risks, incorporating vegetation type, precipitation, climate changes, atmosphere conditions, and weather (NCDC).

A lot of fire events, especially in California, are due to El Niño-Southern Oscillation (ENSO), in particular, La Niña Events. During La Niña, the oceans in the South Pacific become much cooler, however this has a different affect on the west coast and the rest of the United States. During many La Niña events, many counties in California experience a lack of precipitation, leading to drought. The events also give force in building the warm Santa Ana winds. The fall and winter seasons are much windier than normal in Southern California because the polar jet stream periodically dives south along the Rocky Mountains, into the Great Basin states. This flow causes high pressure to build west of the Rockies, generating dry Santa Ana winds that explode off the Mojave Desert into Southern California (NCDC). La Niña plays a big factor in the moisture content of the vegetation regions, and during these events, the dry vegetation provides fuel for a fire to spread.

The flammable vegetation types we have analyzed are monitored constantly by fire protection agencies during drier seasons. Most of these types of vegetation are in open areas with little to no urbanization, however the probability for the wind to carry these into urban locations is very high during La Niña, or dry and windy seasons.

Elevation in San Diego County did not play a large part in the fire events, however a mutual attribute that the fires did have was that no fire was above seventeen-hundred meters. Applying this in ArcMap allowed us to eliminated high elevations even though they have flammable vegetation types.

Conclusion:

Little is known about when and where future fires will occur because the timing and patterns of fires is driven by several factors including a longer fire season, greater climatic variability, and more lightening strikes (Moritz). Although we didn't analyze climate change in particular, our analysis of past temperatures and precipitations as compared to the 2007 data shows that temperatures have increased and precipitation has decreased. It is believed that more fires will occur in California's future because the climate change we are experiencing is leading to hotter days on average and longer fire seasons (Parker). While our analysis provides predictions for future fires in Southern California, we believe that with climate change the occurrence of fires will increase, and the areas where they can easily ignite and spread will cover vast more territory and the weather conditions will be optimized with hotter temperatures, more drought, and stronger Santa Ana winds, perhaps even lasting for longer periods of time. With this information scientists can do future research into how the climate change will change fire locations across the nation; policy makers can be informed of even more consequences of climate change and hopefully one day our government will take the necessary steps to saving our planet.

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