Wildland Fire Risk Zone Mapping in the Southern Part of California Using a Geographic Information System

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Abstract

Southern California experiences moderate to devastating wildfires every year which continue to incur tremendous economic and emotional costs to homeowners and communities. Wildfires are largely caused by southern California's hot and dry weather conditions and human activities near forested areas. Even though fire is an important part of a forest's life cycle, and a natural method of forest management, it may have adverse consequences on the environment. Therefore, it is necessary to determine the factors that drive southern California's fire risk and minimize the losses caused by wildfires. This study uses a Geographic Information System (GIS) to identify the wildland fire risk zones in the southern part of California and compare the predicted fire risk zones to historical fire data. In addition to the fire risk model, this study involved statistical analyses: two-sample t-test and chi-square analysis of contingency tables. The two-sample t-test compared the mean slope of the areas with fires to the mean slope of the areas without fires, which concluded that the mean slope with fires was statistically greater than the mean slope without fires. The chi-square analysis of contingency tables examined the consistency of the proportion of fires in each risk zone in the last ten years. The results show the proportion of fires in each risk zone was not consistent during that time period.

Introduction

In southern California, wildland fire is one of the most frequent natural hazards. According to the Wildfire Today's (2013) report, the Cedar Fire in 2003 burned 276,246 acres land, killed 15 people, and destroyed thousands of homes in San Diego County. The Zaca Fire in 2007 burned 240,207 acres of land in Santa Barbara County. The Springs Fire and the Powerhouse Fire in 2013 burned more than 54,000 acres of land in Los Angeles and Ventura County (Wildfire Today, 2013).

The main objectives of this study were to identify the wildland fire risk zones in the four counties of southern California and evaluate the predicted fire risk model using the historical fire occurrence data from 2004 to 2013.

According to Chuvieco and Congalton (1989), GIS is an integral part of any fire risk study and it helps to combine different environmental factors to establish a fire risk map.

Environmental factors and fire occurrence data take a major part in any study determining the wildland fire risk zones (Chuvieco and Salas, 1996; Jaiswal, Mukherjee, Raju, and Saxena, 2002). Factors considered in prior fire risk studies include fuel, topographic factors (slope, aspect, and elevation), anthropogenic factors (proximity to roads and population), temperature, and humidity (Chuvieco and Congalton, 1989; Jain, Ravan, Singh, Das, and Roy, 1996; Jaiswal *et al*., 2002; Erten, Kurgun, and Musaoğlu, 2002; Ghobadi, Gholizadeh, and Dashliburun, 2012).The integrated approach applied in this study included a number of environmental factors that affect the ignition and spread of a wildland fire.

Study Area

Four counties from the southern part of California were chosen for this study. San Luis Obispo, Santa Barbara, Ventura, and Los Angeles.

The total area covered by these four counties is approximately 37,210 km^2, and the total population is 11,335,455 (Table 1).

Table 1. Study area and total population (United States Census Bureau, 2010).

County	Area (km^2)	Population
San Luis Obispo	9,370	269,637
Santa Barbara	9,810	423,895
Ventura	5,720	823,318
Los Angeles	12,310	9,818,605
Total	37,210	11,335,455

Some of the data used in this study did not include the parts of the counties that are islands. Therefore, to maximize the accuracy and establish a realistic fire model, the islands were excluded from the study area.

The average annual temperature of the study area varies between 60^{o}F – 65^{o}F, the average annual precipitation between 454 mm – 506 mm, and the average annual relative humidity between 78% - 83% (USA.COM, 2014). Climatic factors were not included in this study.

Data and Methodology

Fire Information for Resource Management System (FIRMS)

Remote sensing has been popular for its ability to observe forest resources and monitor wildland fire risk zones. Calle and Casanova (2008) suggested three basic areas in which remote sensing can be directly applied to the subject of wildfires, and these are risk of fire spreading, detection of hotspots and establishment of fire parameters, and delineation of affected areas. According to a report from the Food and Agriculture Organization (FAO) (2007), the Global Observation of Forest and Land Cover Dynamics project has promoted the use of space-borne instruments for detection, monitoring, and calculating the impacts of fires.

FIRMS is another source which provides fire information through Web Fire Mapper, email, and cell phone text messages. FIRMS provides active fire information using the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on board NASA’s Aqua and Terra satellites (NASA\University of Maryland, 2002). This study received fire information as point data in shapefile format through email. The attribute tables of the shapefiles include the following fields: latitude and longitude (center of point location), brightness (brightness temperature measured in Kelvin), scan and track (spatial resolution of the scanned pixel), acqdate (Acquisition date), time (time of the overpass of the satellite), satellite (Terra or Aqua), and confidence (quality flag of the individual hotspot, an experimental field) (NASA/University of Maryland, 2002). Evaluation of the predicted fire hazard model utilized ten years of fire occurrence data. In order to fulfill that requirement, all annual shapefiles were merged into a single shapefile.

Wildland Fires in the Study Area

A depiction of fire occurrences is presented in Figure 1. From the shapefile received, it was possible to obtain data on the number of fires per year in the study area since 2004. The frequency of fire in 2006, 2007, and 2009 ranged from

2000 to 4000, whereas in other years it was less than 1000 (Figure 2).

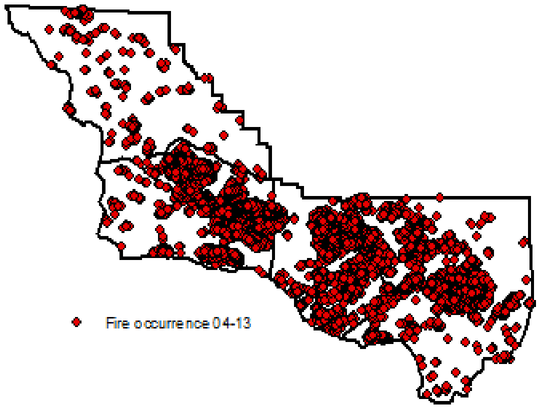

Figure 1. Fire occurrence from 2004 to 2013.

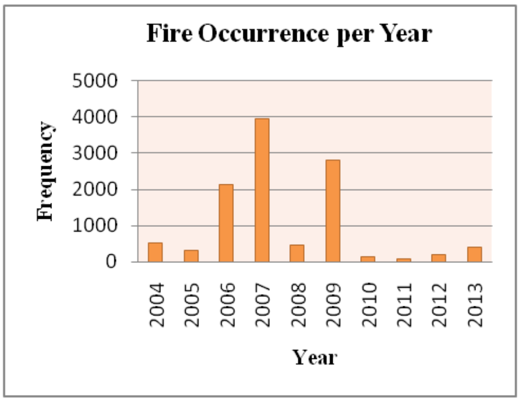

Figure 2. Fire occurrence from 2004 to 2013.

FIRMS's fire data shows Santa Barbara County had the highest number of fires in the ten year period from 2004 to 2013. Ventura and Los Angeles obtained second and third positions respectively (Figure 3).

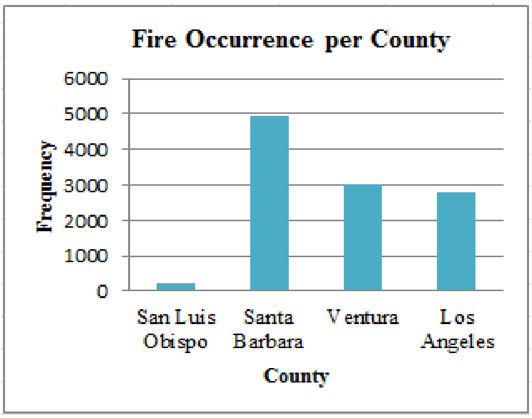

Figure 3. Fire occurrence per county.

Land Cover

Dong, Shao, Limin, Zhanqing, Lei, and Hui (2006) stated fuel represents the material available for fire ignition and combustion. Fuel characteristics include vegetation structure, fuel type, and biomass (Dong *et al.*).

The land cover data selected for this study was in TIFF format with one band, with acquisition year of 2006. The image was further processed on August 15th, 2011. The image was downloaded from the United States Department of Agriculture's (USDA) website.

The data was obtained for the entire state of California, and then the raster was clipped to the study area using the ArcGIS Spatial Analyst Extract by Mask tool (Figure 4).

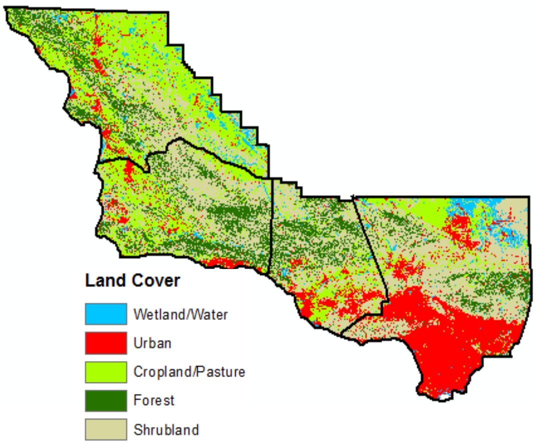

Figure 4. Land cover map illustrating each land cover type.

Topographic Data

Chuvieco and Congalton (1989) stated topography is one of the most significant factors included in any fire hazard rating system. Steep slopes are more prone to fire than gentle slopes, because fire travels rapidly in steep slopes (Chuvieco and Congalton, 1989; Jaiswal *et al.*, 2002; Nasiri, Hojjati, and Tafazoli, 2012). Aspect and exposure are also very much related to the rate of fuel drying and spread of fire (Chuvieco and Congalton, 1989; Castro and Chuvieco, 1998).

For this study, a Digital Elevation Model (DEM) was downloaded from USDA's website and used to create the slope and aspect data for the study area (Figures 5 and 6).

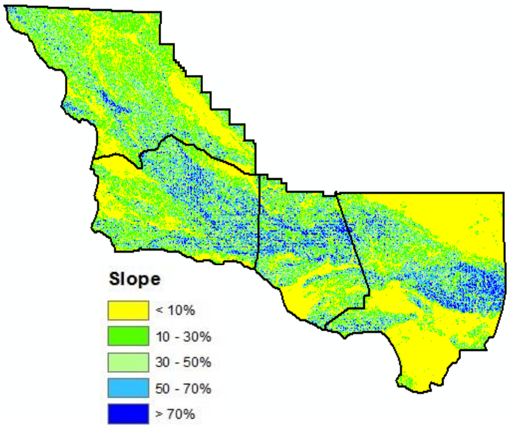

Figure 5. Slope map illustrating percent slope.

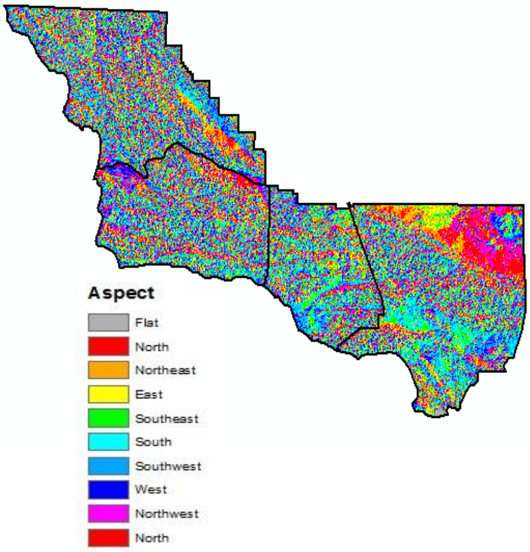

Figure 6. Aspect map illustrating directionality of which direction land faces.

Proximity to Roads and Populated Places

Dong *et al.* (2006) stated anthropogenic factors are described with spatial distribution of certain human infrastructure, such as roads, settlements, camping sites, and farmlands. Chuvieco and Congalton (1989) suggested identifying distance to roads and distance to populated places can be useful to locate the risk areas where a high level of human activities might occur.

For this study, buffers of five intervals were created around the primary and secondary roads of the study area to demarcate the fire risk zones (Figure 7).

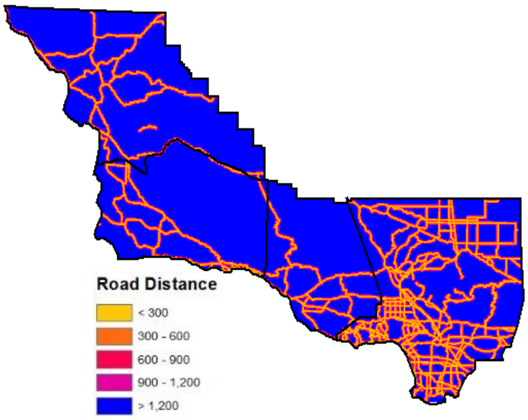

Figure 7. Proximity to roads map illustrating distance from roads in meters.

A similar approach was performed for the proximity to populated places layer. Buffers of four intervals were created around the populated places of the study area to highlight the fire risk zones (Figure 8).

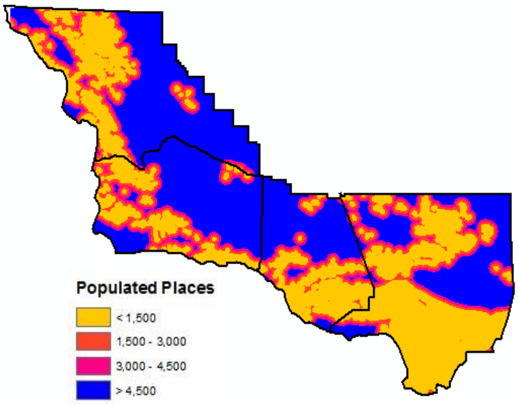

Figure 8. Proximity to populated places map illustrating distance from populated places in meters.

Prior studies have not specifically discussed the reasons behind selecting specific distances from the roads and populated places. Therefore, this study did not follow a predefined standards when selecting the distances.

Integrated Fire Risk Model

Several fire studies have presented the integration of environmental factors into a single fire model (Chuvieco and Congalton, 1989; Calabri, 1990; Erten *et al*., 2002; Jaiswal *et al*., 2002; Carmel, Paz, Jahashan, and Shoshany, 2009; Somashekar, Ravikumar, Mohan Kumar, Prakash, and Nagaraja, 2009; Cáceres, 2011; Ghobadi *et al*., 2012; Sivrikaya, Sağlam, Akay, and Bozali, 2013).

This study integrates five environmental factors in order to establish a wildland fire risk map. The factors include: land cover (fuel), slope, aspect, proximity to roads, and proximity to populated places.

Erten *et al*. (2002) proposed a hierarchical scheme of fire rating (Table 2), which was followed in this study. The factors of importance were organized according to the fire risk level of each factor. The following order of importance was maintained to achieve the final result: land cover, slope, aspect, proximity to roads and proximity to populated places.

The wildland fire risk model can be summarized in the following equation:

$$FR = 7L + 5(S+A) + 3(P_R+P_P)$$

where, FR represents fire risk and L, S, A, P_R, and P_P where the following variables are accounted for: land cover (L), slope (S), aspect (A), proximity to roads (P_R), and proximity to populated places (P_P) respectively.

Establishment of the wildland fire risk model involved several steps. First, environmental factors were weighted depending on the risk level they pose. The land cover was assigned the highest weight, the slope and aspect were assigned the second highest weight, and the proximity to roads and proximity to populated places were assigned the third highest weight. Then, each environmental factor was reclassified and assigned a coefficient from 5 to 1, with 5 being the highest risk.

Table 2. Fire risk model.

Land Cover (Weight 7)		
Classes	**Coefficient**	**Fire Rating**
Shrub land	5	Very high
Forests	4	High
Agriculture	3	Medium
Urban	2	Low
Wetlands	1	Very low
Slope (Weight 5)		
Classes	**Coefficient**	**Fire Rating**
>70%	5	Very high
50-70%	4	High
30-50%	3	Medium
10-30%	2	Low
<10%	1	Very low
Aspect (Weight 5)		
Classes	**Coefficient**	**Fire Rating**
South	5	Very high
South west	5	Very high
South east	5	Very high
West	4	High
East	3	Medium
North	2	Low
North west	2	Low
North east	2	Low
Proximity to Roads (Weight 3)		
Classes	**Coefficient**	**Fire Rating**
<300m	5	Very high
300-600m	4	High
600-900m	3	Medium
900-1200m	2	Low
>1200m	1	Very low
Proximity to Populated Places (Weight 3)		
Classes	**Coefficient**	**Fire Rating**
<1500m	5	Very high
1500-3000m	4	High
3000-4500m	3	Medium
>4500m	2	Low

The land cover was considered as a source of fuel for fire ignition. Fire rating of the land cover classes was determined by the level of moisture; the dryer the vegetation, the higher the risk of flammability (Cáceres, 2011) (Figure 9).

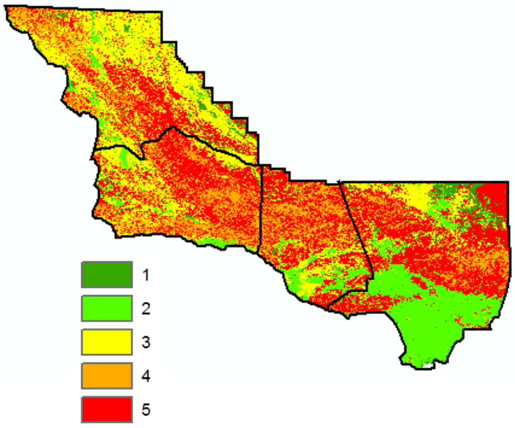

Figure 9. Weighted flammability land cover map of the study area. Areas in green represent low risk zones and areas in red represent high risk zones in the study area.

Slope and aspect were considered as topographic factors; they were assigned the second highest weight. Fire rating of slope was determined by the fact fire travels more rapidly upslope than downslope (Jaiswal *et al*., 2002). Accordingly, slope data was divided into five fire risk categories: greater than 70% (very high risk), between 50% and 70% (high risk), between 30% and 50% (medium risk), between 10% and 30% (low risk), and under 10% (very low risk) (Figure 10).

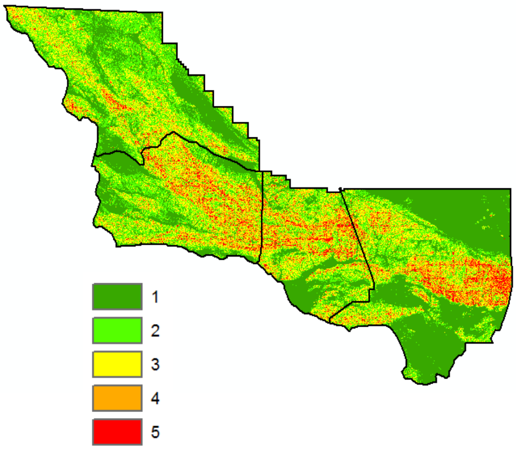

Figure 10. Weighted slope map of the study area. Areas in green represent low risk zones and areas in red represent high risk zones in the study area.

Aspect data for this study were divided into four fire risk categories. In California, due to prolonged exposure to solar radiation, south, southwest, southeast, and west facing slopes receive more direct and daily solar exposure than north, northeast, northwest, and east facing slopes (Fire Management Plan, 2000). For this study, south, southwest, and southeast facing slopes were weighted as very high risk, west facing slopes as high risk, east facing slopes as medium risk, and north, northeast and northwest facing slopes as low risk (Figure 11).

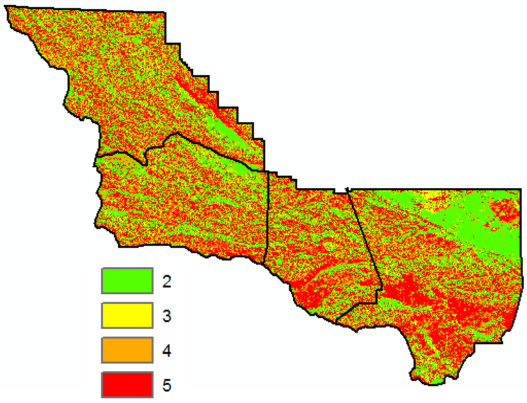

Figure 11. Weighted aspect map of the study area. Areas in green represent low risk zones and areas in red represent high risk zones in the study area.

Proximity to roads was evaluated since the nearby areas pose a higher risk of wildland fire. The proximity to roads layer was divided into five fire risk categories from very high to very low. Areas less than 300 meters from roads were classified as very high risk; areas between 300 meters and 600 meters were classified as high risk; areas between 600 meters and 900 meters were classified as medium risk; areas between 900 meters and 1200 meters were classified as low risk; areas greater than 1200 meters were identified as very low risk (Figure 12).

The proximity to populated places layer had a similar fire rating as the proximity to roads layer. This layer was divided into four fire risk categories. Areas less than 1500 meters from populated places were considered very high risk; areas between 1500 meters and 3000 meters were classified as high risk; areas between 3000 meters and 4500 meters were classified as medium risk; and areas greater than 4500 meters were classified as low risk (Figure 13).

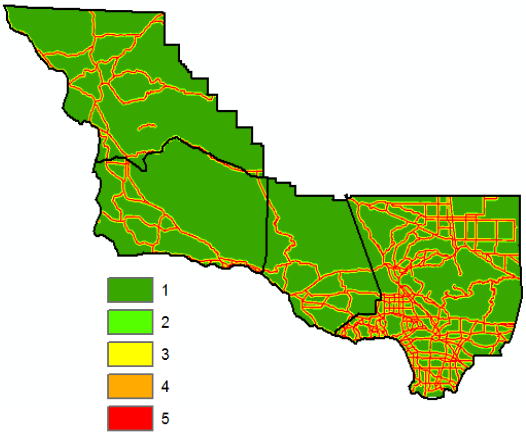

Figure 12. Weighted proximity to roads map. The proximity references meters. Areas in green represent low risk zones and areas in red represent high risk zones in the study area.

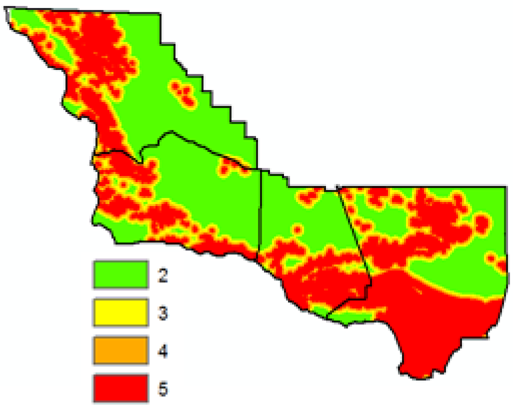

Figure 13. Weighted proximity to populated places map. The proximity references meters. Areas in green represent low risk zones and areas in red represent high risk zones in the study area.

Creating the Fire Risk Map

The main objective of this project was to identify the wildland fire risk zones using the environmental factors. In order to achieve that result, all weighted factors were combined using Esri's Spatial Analyst Raster Calculator tool. The output was a raster layer which was further utilized in the criterion based analysis in order to identify the five fire risk zones. Erten *et al*. (2002) proposed a criterion based analysis which was followed in this study (Tables 3 and 4).

The output raster generated from the combined weighted factors contained a range of values from 31 to 115. Table 3 presents a criterion based analysis which shows the raster value at the upper limit of each fire risk zone as well as the description of the upper limit of each risk zone. Table 4 presents the values of the output raster used to identify each fire risk zone and create an integrated fire risk map (Figure 14).

Table 3. The upper limit of each fire risk zone by raster value and its description.

Fire Sensitivity	**Description of Wildland Fire Risk Zones**
Very high VH+VH+VH+ VH+VH = 115	An area where slope is greater than 70% on the south, that is within 1500 m far from populated places and 300 m from roads and covered by shrub lands.
High H+H+H+H+H = 92	An area where slope is between 50% and 70% on the west, that is 1500-3000 m far from populated places and 300-600 m from roads, and covered by forests.
Medium M+H+M+M+M = 74	An area where slope is between 30% and 50% on the west, that is 3000-4500 m far from populated places and 600-900 m from roads, and covered by cropland, herbaceous, and pasture.
Low L+M+L+L+L = 51	An area where slope is between 10% and 30% on the east, that is more than 4500 m far from populated places and 900-1200 m from roads, and covered by urban areas.
Very low VL+L+L+L+V L = 34	An area where slope is less than 10% on the north, that is more than 4500 m far from populated places and 900-1200 m from roads, and covered by wetlands and open water.

Table 4. Values representing each fire risk zone.

Fire Risk Zone	Values Represent Each Risk Zone
Very high	>92
High	74 – 92
Medium	51 – 74
Low	34 – 51
Very low	<34

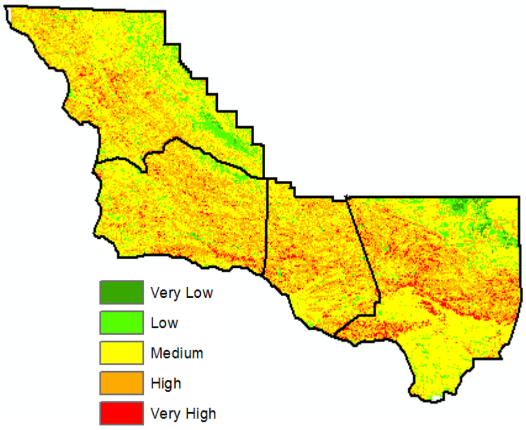

Figure 14. Integrated fire risk map illustrating fire risk zones.

Evaluation of the Predicted Fire Risk Model

The purpose of this project also involved evaluating the predicted fire hazard model with the ten years of fire occurrence data. This evaluation was performed using the Spatial Analyst Extract Values to Points tool. This tool extracts raster values from the final fire hazard layer for each fire point. The percentage of fire occurrence in each fire risk zone was evaluated (Table 5).

Table 5. Percentage of fire occurrence in each fire risk zone.

Fire Risk Zone	Percentage of Fires
Very high	7%
High	45%
Medium	47%
Low	1%
Very low	0%

From Table 5, 52% of fires occurred in the very high and high risk zones, 47% of fires occurred in the medium risk zone, and only 1% of fires occurred in the low and very low risk zones.

Statistical Analysis

Two- Sample t-Test

This project also incorporated statistical analyses to evaluate how the historical fire locations compared to the fire risk zones. In order to examine the fact that steep slopes are more prone to fires than gentle slopes (Chuvieco and Congalton, 1989; Jaiswal *et al*., 2002) a two-sample t-test was performed on the slope data. In this test, the null hypothesis stated the mean slope of areas having fires is less than or equal to the mean slope of the areas not having fires, whereas the alternate hypothesis stated the mean slope of the areas having fires is greater than the mean slope of the areas not having fires. The presence and absence of fire in the cells were indicated with 1 and 0 respectively. The test was performed in the SPSS software considering 95% confidence interval and the alpha value (α) as 0.05. The F- test determined equal variances could not be assumed; therefore, the test was run assuming unequal variances.

The result of the one-tailed t-test rejected the null hypothesis ($p=0.000$) and showed the mean slope for the areas having fires was statistically greater than the mean slope of the areas not having fires. Table 6 shows the mean slope with fires is 39.73, while the mean slope without fires is 31.31. Overall, the slope is higher in the areas where fires exist.

Table 6. SPSS results of two-sample t-test.

Fire Code	N	Mean	Std. Deviation
1	2480	39.73	21.494
0	4191820	31.31	20.113

Chi-Square Analysis of Contingency Tables

In addition to the two-sample t-test, a chi-square analysis of contingency tables was used to compare the final fire risk map and historical fire occurrence data. The objective of this analysis was to test the consistency of the proportion of fires in each risk zone in the last ten years. The first chi-square analysis was attempted with ten rows (for the ten years of fire data) and four columns (for the four fire risk categories). Since the very low risk category was lacking fire data for most of the years, this category was merged with the low risk category to be used as a single column. The ArcGIS Spatial Analyst Extract Values to Points tool was used to determine the observed number of fires (Figure 15) in each risk category. The expected frequencies were calculated using the following formula:

$$EF = (TP/TA) * TC$$

where, EF = Expected frequency, TP = Total number of fires per year, TA = Total number of fires for all years, and TC = Total number of fires per fire risk category.

The analysis produced a high chi-square value (411.18) and failed to support the null hypothesis, which stated that the proportion of fires in each risk zone was consistent year to year (in the last ten years).

In order to know the reason behind the high chi-square (χ^2) value, the subdivision of contingency tables was incorporated into this study. Table 7 presents the chi-square (χ^2) value for each cell. From this table it is clear the low fire risk column had the highest contribution (152.34) in the final chi-square (χ^2) result.

The subdivision of the contingency table was performed suspecting that the significant chi-square (χ^2) value was due largely to the high chi-square (χ^2) values in the low risk column.

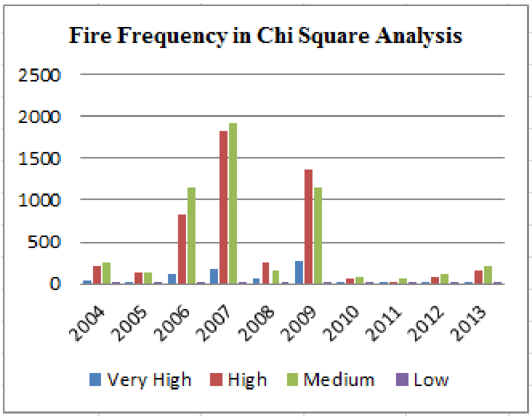

Figure 15. Observed frequency of fire in chi-square (χ^2) analysis.

Table 7. Chi-square (χ^2) value for each cell and total chi-square (χ^2) value per category.

Year	VH	H	M	L
2004	0.09	1.23	0.13	13.99
2005	0.56	0.20	0.06	0.34
2006	4.18	15.46	21.25	0.07
2007	27.94	3.06	1.01	20.78
2008	30.41	8.13	23.82	0.20
2009	38.44	8.50	24.34	1.40
2010	2.00	2.04	0.29	71.78
2011	2.24	14.72	13.28	15.08
2012	1.93	4.32	1.84	0.73
2013	0.12	5.11	2.14	27.97
Total	**107.91**	**62.77**	**88.16**	**152.34**

To test that supposition, the low risk column was removed and the analysis was performed using the ten rows and three columns. The analysis yielded a high chi-square (χ^2) value (258.69) which failed to support the null hypothesis. Table 8 presents the chi-square (χ^2) value for each cell. This table shows the very high risk column contributed the highest value in the final chi-square (χ^2) result.

Table 8 shows the column very high contributed the highest value in the previous chi-square (χ^2) result. This column was removed from the analysis, and the analysis was performed with ten rows and two columns (Table 9). Similar to the previous results, the chi-square (χ^2) result (144.58) failed to support the null hypothesis.

Table 8. Chi-square (χ^2) value for each cell and total chi-square value (χ^2) per category.

Year	VH	H	M
2004	0.17	0.70	0.43
2005	0.54	0.24	0.04
2006	4.21	15.61	21.05
2007	29.12	1.96	0.42
2008	30.61	8.35	23.54
2009	37.92	7.97	25.20
2010	1.48	0.68	1.56
2011	2.00	13.19	16.34
2012	2.01	4.08	2.04
2013	0.04	3.57	3.62
Total	**108.1**	**56.35**	**94.24**

Table 9. Chi-square (χ^2) value for each cell and total chi-square value (χ^2) per category.

Year	H	M
2004	0.58	0.54
2005	0.12	0.11
2006	18.53	17.38
2007	0.16	0.15
2008	16.49	15.47
2009	16.24	15.24
2010	1.07	1.01
2011	14.53	13.63
2012	3.18	2.98
2013	3.70	3.47
Total	**74.6**	**69.98**

Therefore, through the series of subdivisions and column combinations of the original table, conclusions support the proportion of fires in each fire risk category was not consistent in the last ten years.

Results

Apart from evaluation of the predicted wildland fire hazard model, historical fire occurrence data was utilized in analyzing the significance of each environmental factor in the wildland fire.

In the land cover layer, shrub lands, forests, and herbaceous /croplands occupied 78.31% of the area and these three land cover classes were categorized as very high, high, and medium risk respectively. Of the historical fires, 5,876 fires occurred in the shrub lands, 3,463 fires occurred in the forests, and 1,103 fires occurred in the herbaceous/ croplands. Fire results showed 94.68% of the total fire occurred in these three land cover classes (Figure 16). Therefore, this information suggests land cover had an influence on wildland fire occurrence.

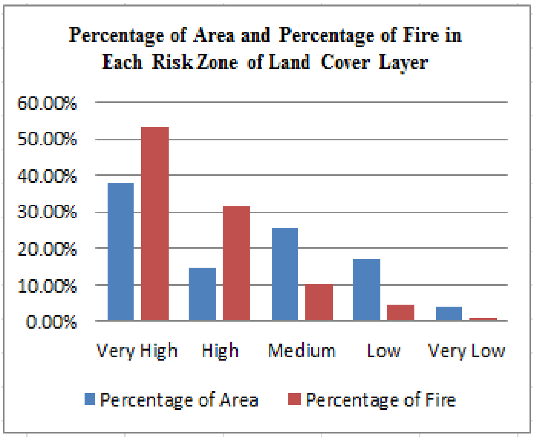

Figure 16. Bar graph showing the percentage of the study area and percentage of fires in each risk zone of the land cover layer.

The outcome of the slope analysis yielded five fire risk zones (Figure 17). Using historical fire occurrence data, 68% of fires occurred in the very high, high, and medium risk zones, whereas only 32% of fires occurred in the low and very low risk zones. From this fire information, it appears slope greater than 30% had an influence in the wildland fires.

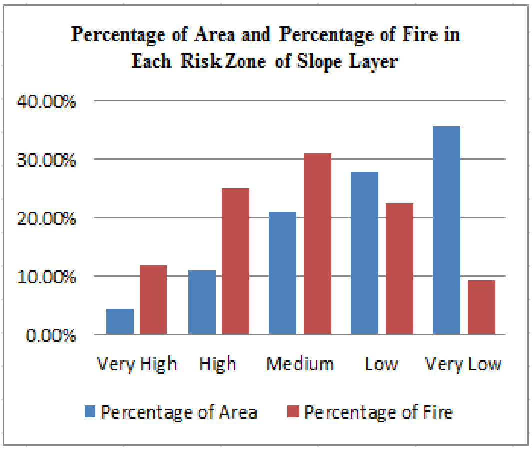

Figure 17. Bar graph showing the percentage of the study area and percentage of fires in each risk zone of the slope layer.

Analysis of the aspect layer resulted in four fire risk zones: very high, high, medium, and low (Figure 18). In the last ten years 4,601 fires occurred in the very high risk zone, 1,322 fires occurred in the high risk zone, 1,282 fires occurred in the medium risk zone, and 3,824 fires occurred in the low risk zone. The history of fire occurrence showed 54% of fires occurred in the south, south west, south east, and west facing slopes, whereas 46% of fires occurred in the north, north west, north east, and east facing slopes. It appears southern aspect had an influence in the wildland fires.

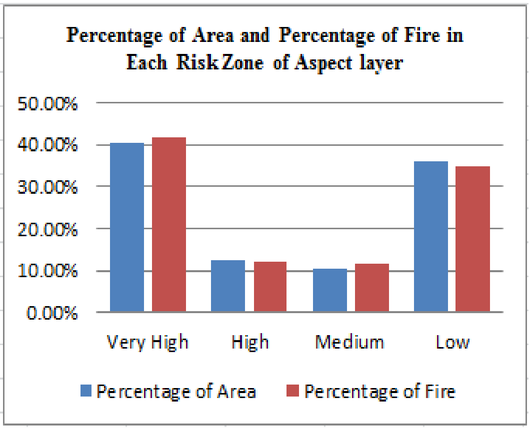

Figure 18. Bar graph showing the percentage of the study area and percentage of fires in each risk zone of the aspect layer.

Analysis of proximity to roads layer resulted in five fire risk zones from very high to very low (Figure 19). The history of fire occurrence showed only 12% of fires occurred in the very high, high, medium, and low risk zones, whereas 88% of fires occurred in the very low risk zone. From this fire information, findings support proximity to roads was not a major contributor to wildland fires in the study area. Potential reasons behind the high percentage of fires in the very low risk zone could be the large amount of area in that zone which also coincides with the higher risk zones of the land cover, slope, aspect, and proximity to populated places layers.

The outcome of the proximity to populated places layer yielded four fire risk zones from very high to low.

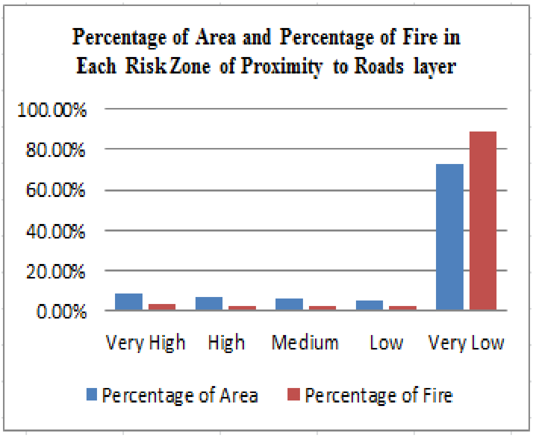

Figure 19. Bar graph showing the percentage of the study area and percentage of fires in each risk zone of the proximity to roads layer.

The history of fire occurrence showed 72% of fires occurred in the low risk zone, whereas only 28% of fires occurred in the very high, high, and medium risk zones. Similar to the proximity to roads layer, this layer also had a large amount of area in the low risk zone which coincided with the higher risk zones of other environmental factors. Therefore, conclusions support proximity to populated places was not a major contributing factor in the wildland fires (Figure 20).

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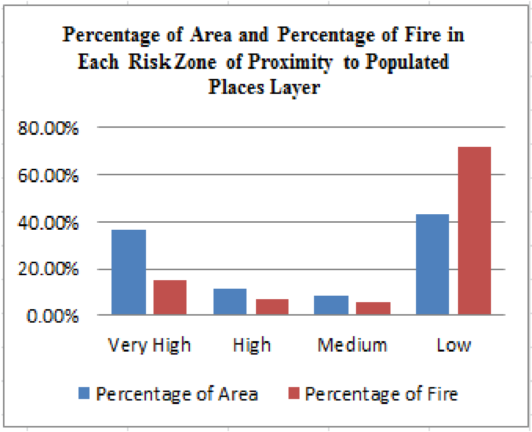

Figure 20. Bar graph showing the percentage of the study area and percentage of fires in each risk zone of the proximity to populated places layer.

After analyzing contributions of all environmental factors, land cover had the maximum influence in this wildland fire study. Slope and aspect were considered as the second most influential factors, whereas proximity to roads and proximity to populated places failed to show any contribution. Moreover, results matched the weighting strategy followed in this study to organize environmental factors according to risk level in wildland fires.

The outcome of the integrated analysis was a wildland fire risk map composed of five fire risk zones from very high to very low (Figure 21). The risk zones selected in this study were based on the criterion based analysis. The risk zones and their ranges are presented in Table 10.

Table 10. Wildland fire risk results.

Classes	Risk Zone	Area in Km^2
>92	Very high	1275.86
74-92	High	8884.51
51-74	Medium	17512.83
34-51	Low	2308.16
<34	Very low	196.18

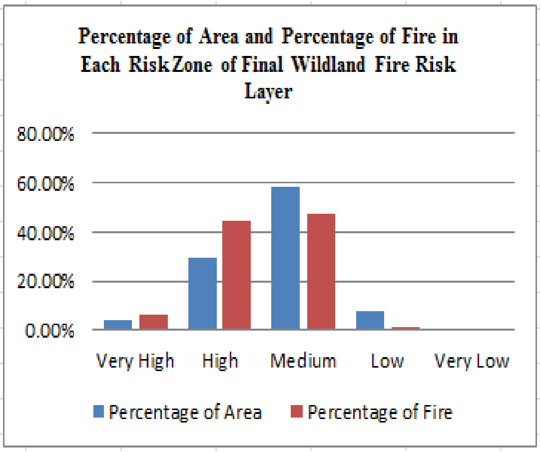

Figure 21. Bar graph showing the percentage of the study area and percentage of fires in each risk zone of the wildland fire risk layer.

Using historical fire occurrence data, it was possible to determine the number of fires occurring in each fire risk zone and compare the results. Results showed a total of 5,645 fires occurred in the very high and high risk zones, 5,247 fires occurred in the medium risk zone, and a total of 137 fires occurred in the low and very low risk zones. From this historical fire information, in the last ten years most of the fires occurred in the very high, high, and medium risk zones. High percentages of fire in the medium risk zone could be partly due to the existence of a large amount of area (17,512.83 km^2) in that zone which coincides with the shrub lands, forests, steep slopes, or southern/western aspect.

The chi-square analysis of contingency tables incorporated in this study aimed to test the consistency of the proportion of fires in each risk zone in the last ten years and the result showed the proportion of fires in each risk zone was not consistent in the last ten years. This proportional inconsistency could be attributed to changes in environmental factors during the time period.

Conclusion

GIS was used in this study to integrate environmental factors responsible for wildland fires, which in turn creates a fire risk map composed of several fire risk zones. FIRMS provided important fire information which was utilized in the evaluation of the predicted fire risk model as well as to analyze the significance of each environmental factor in this wildland fire study. Fire information showed over 98% of fires occurred in the very high, high, and medium risk zones.

This project also applied statistical analyses of the GIS data used in this study. The slope data was utilized in the two-sample t-test to compare the mean slope of the areas having fires with the mean slope of the areas not having fires. Results failed to support the null hypothesis and concluded that the mean slope with fires is greater than the mean slope without fires. In addition to this analysis, chi-square analysis of contingency tables was performed on the final fire risk map and historical fire data to see whether the proportion of fires in each fire risk category was consistent in the last ten years. Results failed to support the null hypothesis even after performing a series of subdivisions and combination of columns of the original table. Future work could include chi-square analysis of contingency tables for each environmental factor using the historical fire data. This was not possible for this study due to time restrictions.

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