FOREST FIRE RISK ZONE MAPPING FROM SATELLITE IMAGERY AND GIS A CASE STUDY

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ABSTRACT:

Forest fires are one of the major natural risk in the Mediterranean countries. In such areas, fires occur frequently and there is a need for supranational approaches that analyse wide scenarios of factors involved and global fire effects. It is impossible to control nature, but is possible to map forest fire risk zone and thereby minimise the frequency of fire. Fire risk must involve both ignition and spreading risk. It is necessary to be able to estimate the spread of fire starting in any stand of a forest, giving the burning conditions. Spreading of forest fire can impose a threat to the natural coverage of land and safety of population. Early detection of forest fires is essential in reduction of fire damage. Satellite data plays a vital role in identifying and mapping forest fire and in recording the frequency at which different vegetation types/zones are effected. A geographic information system (GIS) can be used effectively to combine different forest-fire causing factors for demanding the forest fire risk zone map. A risk model for fire spreading is set up for Gallipoli Peninsula as a pilot zone, because it continually faces a forest fire problem. It is based upon a combination of remote sensing and GIS data. In this study, the LANDSAT satellite images were used. In order to search the effects of the fire occurred in the region on the 25th July 1994, the satellite images both before the fire and after the fire were used. Parameters that effect the fire such as topography and vegetation with the other land use information including population, settlements, forest fire towers, fire stations, intervention places, the characteristics of the staff that will intervene and transportation were integrated within GIS. The shortest way of intervention during the disaster and the areas to be emptied were questioned. For these analyses ARCGIS software was used. Land use information were obtained from the satellite images in this study. In this phase the distinction of spices in the forest was determined using supervised classification. The lands that have priorities in case of fire were decided by combining the moisture of the land and slope classes that were determined by conventional approaches with the satellite images. The results of the analysis were shown by reports and graphics. The test region results should be applied all over Turkey.

1. INTRODUCTION

It is possible both to control nature and also to map risk zone and thereby to minimise the frequency of fire and avert damage. Forest fire risk zones are locations where a fire is likely to start, and from where it can easily spread to other areas. A precise evaluation of forest fire problems and decision on solutions can only be satisfactory when a fire risk zone mapping is available (Jaiswal et al, 2002).

In Turkey, forest fire is still one of the greatest natural hazard problems. According to the study, last six decades, 1.504.245 ha of the forests has been affected by fire. In other words, it shows annual affecting forest areas over 24.000 ha. In addition to this, along the cost line from Antalya to İstanbul, approximately 12 billion hectares forests are in the first order fire sensitive region.

For these reasons, 133627 km roads and 17219 km fire safety bands have been constructed to prevent forest fire; moreover, forests are watched by 779 fire watchtowers and 17561 unit various radios are used to communicate among these watchtowers. Fire Operation Centre was established in Ankara in 1997. This centre serves 24 hours to monitor forest fire and to coordinate logical support or to communicate.

Satellite remote sensing has opened up opportunities for qualitative analyses of forest and other ecosystems at all geographic and spatial scales. Monitoring and detecting forest fires have also been effectively used in this study. Understanding the behaviour of forest fire, the factors that contribute to making an environment fire prone, and the factors that influence fire behaviour are essential for forest fire (Chuvieco and Congalton, 1989).

In the present study, an attempt was made to prepare a forest fire risk zone map by integrating a satellite image, topographical and other ancillary data from a geographic information system (GIS) for the Gallipoli where is the most forest fire sensitive area in Turkey. This study is also an attempt to exploit the capabilities of remote sensing and GIS techniques and to suggest an appropriate methodology for forest fire risk zone mapping. Such maps will help forest department officials prevent or minimize fire risk activities within the forest and take proper action when fire breaks out (Chuvieco and Sales, 1996).

2. THE AREA OF STUDY

In the area, that is 4.079 hectare and is located in the boundaries of the of the Gallipoli Peninsula Historical – National Park in Ecebat in Çanakkale, a fire broke out and was extinguished in about three days . The area of study is located between the following coordinates: 40^o 41' 32'' - 40^o 22' 45'' northern parallels, and 26^o 12' 57''-26^o 25' 23'' eastern meridians as they are shown in figure 1. 674 hectare of the burned area was the destroyed area, and 3.375 hectare of it was the productive forest.

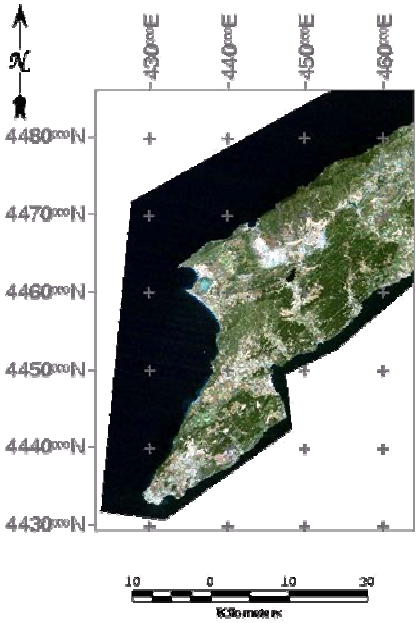


Figure 1. Location of the area of study.

2.1 Vegetation Type

The Gallipoli Peninsula is located over an area of 1684.02 km2 and is rich in forest resources. 23% of the total area in the forest is consisted mostly of pine trees together with other species with leaves and groups of bushes. This kind of vegetation is especially susceptible to fire.

2.2 Climate

The climatic regime determines the vegetation in a particular region, and hence plays a dominant role in creating areas prone to fire. The study area has the Region of Marmara's climate that has the peculiarity of transition from the Region of Black Sea's climate to that of the Region of Mediterranean. In this climate type, it is cold in winter, hot in summer and rainy in spring and autumn.

Annual Low Rain 475.8 mm
Annual Low Temperature 14.4 C
Annual Relative Humidity 80 %
Annual Wind Speed 4.5 m/sec
The Faster Wind Direction South-South/East 30 m/sec

Even though the annual wind speed is about 4.5 m/ sec, it was about 75 km/ sec. on the day the fire broke out.

2.3 Topography

Topography is an important physiographic factor, which is related to wind behaviour, and hence affects the fire proneness of the area. Fire travels most rapidly up slopes and the least rapidly down slopes. The historical peninsula has an uneven land structure. Its structure is mountainous faulted and is consisted of slopes.

2.4 Distance from roads

Forests that are accidental / man-made can be resulted by the movements of humans, animals and vehicles. Thus, forests that are near roads are fire prone. Many roads traverse the study area. This makes people and animals grazing there the cause of fire in the forest.

2.5 Distance from settlements

Forests located near settlements can be said to be more fire prone since the people living there can cause an accidental fire. Crowded settlements are located within the forest in the study area, so they can cause forest fires.

3. MATERIALS AND METHODS

3.1 Data

The images of Landsat TM in 1992 before the fire and the images of that in 1998 after the fire were used for defining and identifying the burned area and for estimating the vegetation loss. Besides the satellite data, the topographic maps were used in this project. The data collected for this study area were the following: forest type map, vegetation map, elevation, slope, aspect, standard topographic map and climate data (average wind, rainfall data, and temperature).

3.2 Methods

Standard topographic maps at a scale of 1:25 000 were digitized and DEM were produced for the study area (figure 2).

Figure 2. DEM

The satellite images were corrected for the influence of atmosphere and topographic relief. These data were geo-coded by the help of rectified SPOT data according to the European Datum (ED50) and a UTM projection to combine and analyse with the other data. In the end, the atmospherically, radio metrically and geometrically corrected / geo-coded images were supplied by ERDAS software.

The purpose of digital land cover classification is to link the spectral characteristics of the image to a meaningful information class value, which can be displayed as a map so that resource managers or scientists can evaluate the landscape in an accurate and cost effective manner (Weber and Dunno, 2001). In this study, the Maximum Likehood supervised classification algorithm was used (Lillesand Kieffer, 2000). The best way to compare images from different dates is to classify the two images separately and to compare the statistical results. The classification of satellite images were utilised in land cover analyses and in determining change between the land use before the fire and that after the fire.
In order to obtain effective and more accurate conclusions, mathematical operations in the GIS analysis were formed. The input information on forest fire influencing factors indicates the weights in the fire risk in an area. The factors were analysed in the following order of importance: vegetation type, slope, aspect, distance from roads and settlements. First classes represent high risk places and last classes represent the minor risk place. Each class has different weights.

The vegetation types were classified according to the moisture context that has an influence on breaking out forest fire. For example, the vegetation type that is very dry is the most flammable whereas the fresh type is inflammable.

Slope influence behaviour of fire was evaluated the second highest weight. Fire travels most rapidly up-slopes and least rapidly down-slopes. Slope classes were created according to this rule. Aspect was assigned equal weight with slope. Since the sunlight is much more reflected on the slopes in the south, fire breaks out fast and spreads in the south sides.

Distance from roads and settlements were evaluated the third highest weight. The risk factor decreases farther from these places. It means that a zone close to these places were evaluated a higher rating.

Water bodies areas do not affect the forest fire risk. These zones have no weights in determination of fire rating class.

The equation used in GIS to determine forest fire risk places is shown in equation 1.

$$RC = 7*V_T + 5*(S+A) + 3*(D_R+D_S) \quad (1)$$

In this equation, RC is the numerical index of forest fire risk zones where V_T indicates vegetation type with 5 classes, S the slope factor with 5 classes, A the aspect variable with 4 classes, D_R and D_S indicate distance factor from road and settlement. Finally, based on these analysis carried out, a fire risk zone map was produced.

3.3 GIS

Geographic Information System (GIS) has also developed functions such as analyzing available information and using them as a decision and a support system as well as it compiles the information as a whole and stores it.

In that way, GIS analyses show the spatial distribution of the observed forest condition and also may help to find cause parameters for the observed – and classified – forest decline phenomena. The link between remote sensing results and an efficient forestry GIS can therefore work as a tool for an operational and practically oriented monitoring system for forest damage assessment and management. It may play an important role as a planning tool for forest and land-use affairs in a broader sense (Faber et al., 1994).

Parameters	Weight	Classes	Factors	Fire Rating classes
Vegetation	7	Very dry	5	Very High
		Dry	4	High
		Moist	3	Medium
		Fresh-like	2	Low
		Fresh	1	Very Low
Slope	5	> % 35	5	Very High
		% 35-25	4	High
		% 25-10	3	Medium
		% 10-5	2	Low
		< % 5	1	Very Low
Aspect	5	South	5	Very High
		West	4	High
		East	3	Medium
		North	2	Low
Distance from roads	3	< 100m	5	Very High
		100-200m	4	High
		200-300m	3	Medium
		300-400m	2	Low
		> 400m	1	Very Low
Distance from settlements	3	< 1000m	5	Very High
		1000-2000m	4	High
		2000-3000m	3	Medium
		> 3000m	2	Low

Table 1 The weight of parameters in determination of fire risk areas.

4. RESULTS

4.1 Image Processing Results

For the indication of forest fire risky places, a land use and vegetation map was prepared using Landsat TM data. The selection of the bands that was used for classification was made taking under consideration the spectral profile analysis. According to the analysis, Landsat TM bands 4, 5 and 7 were selected to make supervised classification. Standard topographic maps were used to indicate the control areas. Classification accuracy was determined by using 50 random pixels. Classification results are shown in the figure 2 and 3. The images were classified into eight classes as forest1, forest2, forest3, non forest, sea, lake, fog and sea shore using maximum like hood algorithm (figure 3 and 4). First, 1992 land use results were obtained. Then, the status of the land use in 1998 was examined. By subtraction of the two classification results, two important changes were indicated. These were acceleration in forest and lake areas. In spite of the fact that the classification accuracy results were % 93.75 and % 90.26, the cloud class in 1992 image was misleading in determination of changes in forest classes.

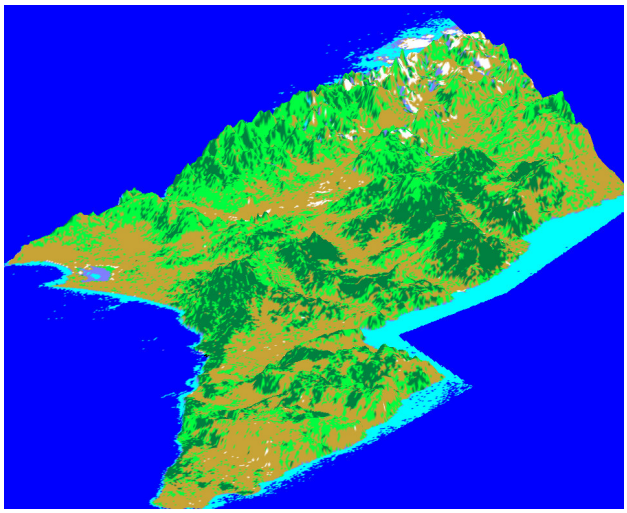


Figure 4. The result of 1992 Landsat image classification that was integrated with DEM

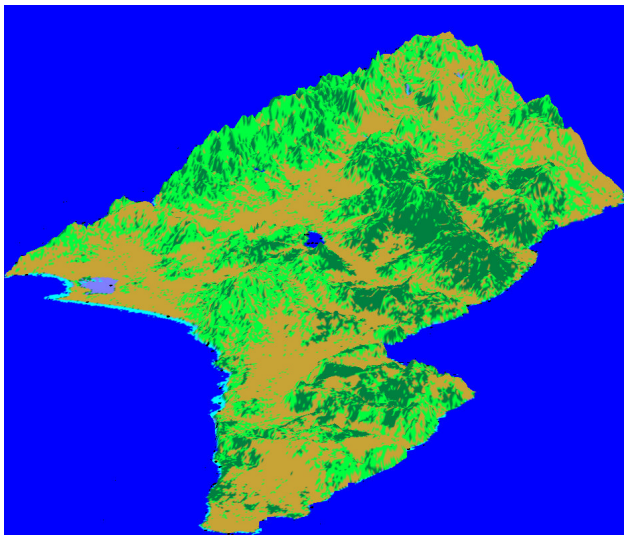


Figure 3. The result of 1998 Landsat image classification that was integrated with DEM

Land use information is an important factor in determination of forest fire risk. Because of this, land use classes obtained from satellite images were converted to vector file and integrated into GIS.

4.2 GIS results

The information system was formed in MapInfo software having transferred the parameters of vegetation type, topography, distance from roads and settlements into a database that are important in determination of forest fire risk. For the production of the forest fire risk map, five fire rating classes are used. These classes are formed according to slope, aspect, vegetation type, distance from roads and settlements. Slope and aspect image
were generated using the DEM data (Fig 5 and 6). Aspect and slope plays a vital role in spreading of the fire. Fire travels most rapidly up-slopes and least rapidly down-slope. Southern slopes are more vulnerable to catching fire.

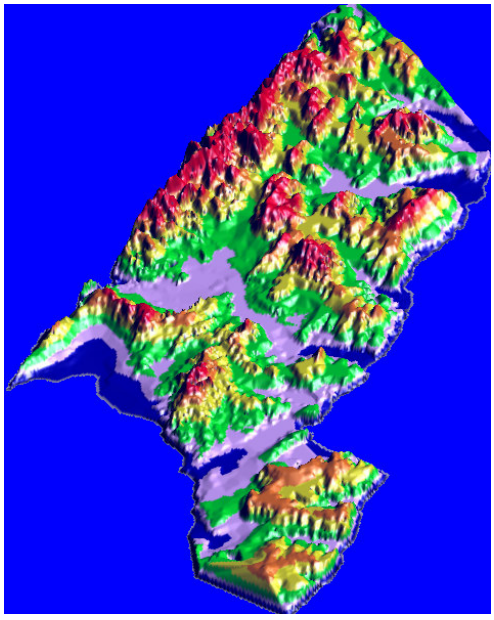
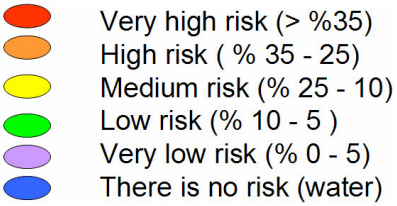


Figure 5. The result of query on slope



Aspect and Slope were examined in ER Mapper software. For the aspect query, aspect filter was used which calculates the aspect or direction of slope for a DEM. The numbers output from the Aspect filter range from 0 to 361. Zero indicates a north facing slope, 90 indicates an east facing slope and so on. The special number 361 is used to indicate areas that are perfectly flat (water) with no aspect for the slope.

The map of the cultivation environment for the area in which the fire broke out (figure 7) was produced according to the vegetation type map. In accordance with this map, very dry, dry, moist, fresh and fresh-like areas were designated and classified into risk classes in terms of the water they contained.

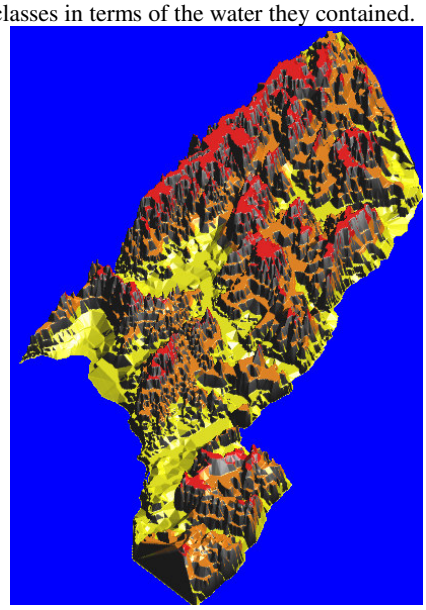
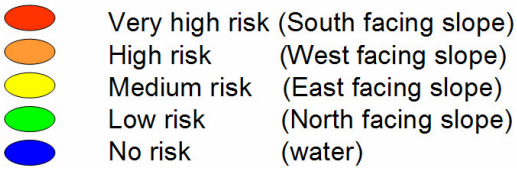


Figure 6. The result of aspect query



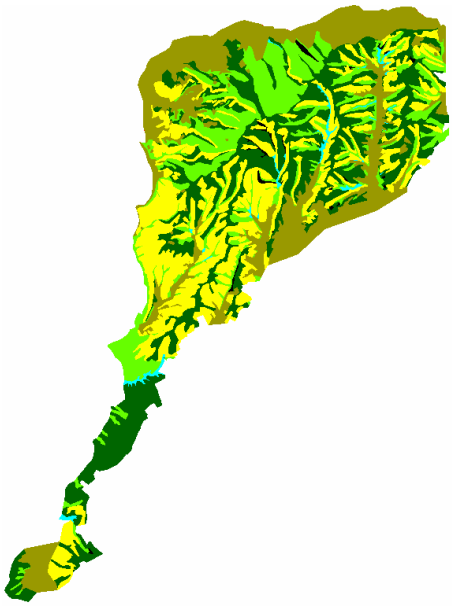
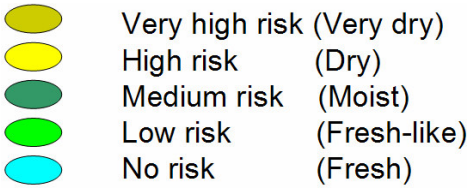


Figure 7. The map of the cultivation environment



Vegetation, road and settlement maps from the test area were digitised and made available in a GIS data base. Buffer zones were created around the roads and settlements. Distances from the centre of the settlement were created around the centre as a polygon data (figure 8). Similarly, buffer zones of distance from the roads were created around the roads (figure 9). The closer the forest are to the roads and settlements, the more probable a fire will break out. According to this, buffer zones were integrated to fire rating classes.

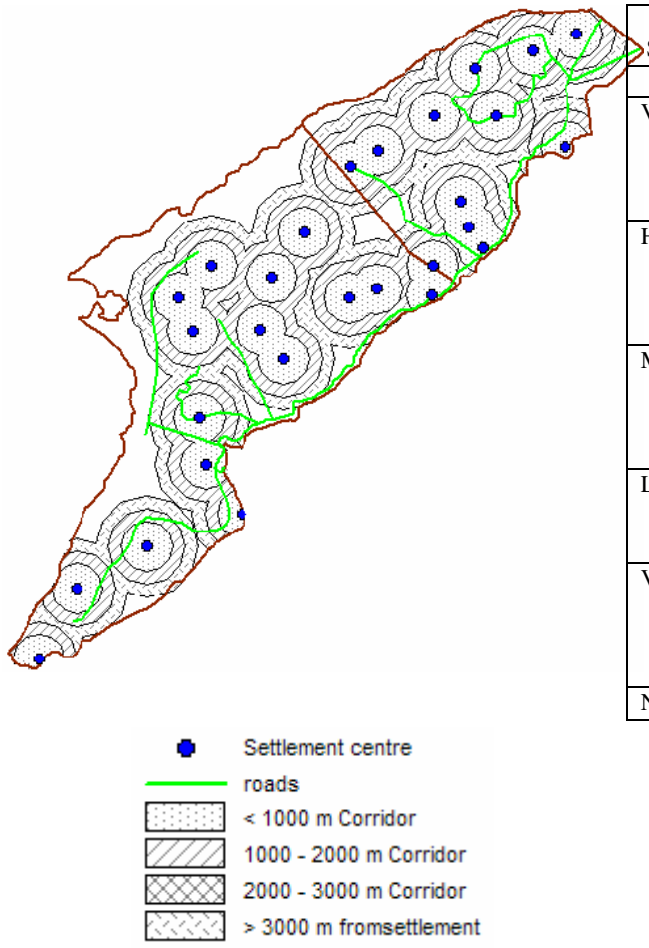


Figure 8. Settlement buffer map of the study area

Fire Sensitivity	Description of the forest fire risk areas
Very High	An area in that slope is more than % 35 on the south, that is 1000 m far from the centre of settlements and 100 m from the roads , and is covered with very dry plants
High	An area in that slope is between % 35 and % 25, that is 1000-2000 m far from the centre of settlements and 100-200 m from the roads, and is covered with dry plants
Medium	An area in that slope is between % 25 and % 10 on the west, that is 2000-3000 m far from the centre of settlements and 200-300 m from the roads, and is covered with moist plants
Low	An area in that slope is between % 10 and % 5 on the east, that is 200-300 m from the roads , and is covered with fresh-like plants
Very Low	An area in that slope is between % 5 and % o on the north, that is more than 3000 m far from the centre of settlements and 400m from the roads, and is covered with fresh plants
No Risk	Lake, water

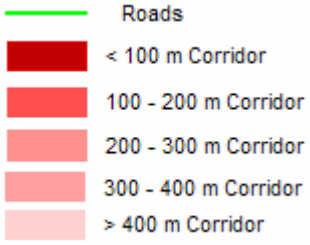
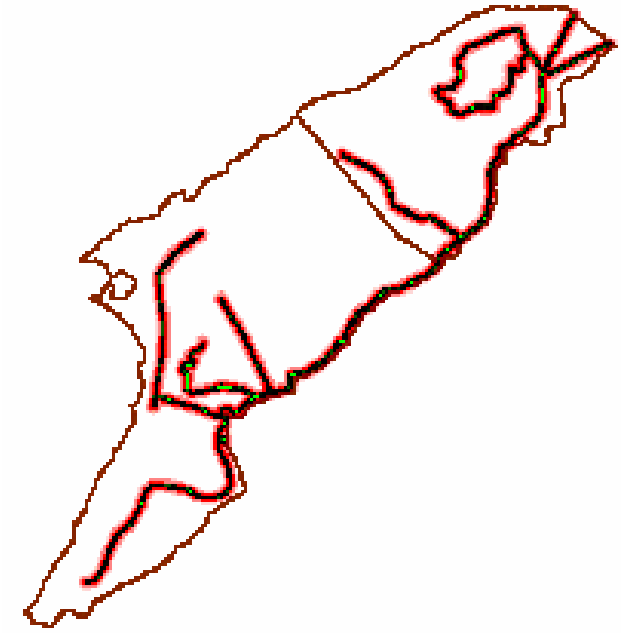


Figure 9. Roads buffer map of the study area



Based on equation (1) and query, forest fire risk zones were determined. The resultant fire risk zones and their properties are described in table 2.

4. CONCLUSIONS

Satellite data are suitable instruments to introduce and classify forest places when integrating the parameter topography, vegetation type, vicinity to roads and settlements. The integration of this satellite data into GIS can be very useful to determine risky places and to plan forestry management after fire.

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