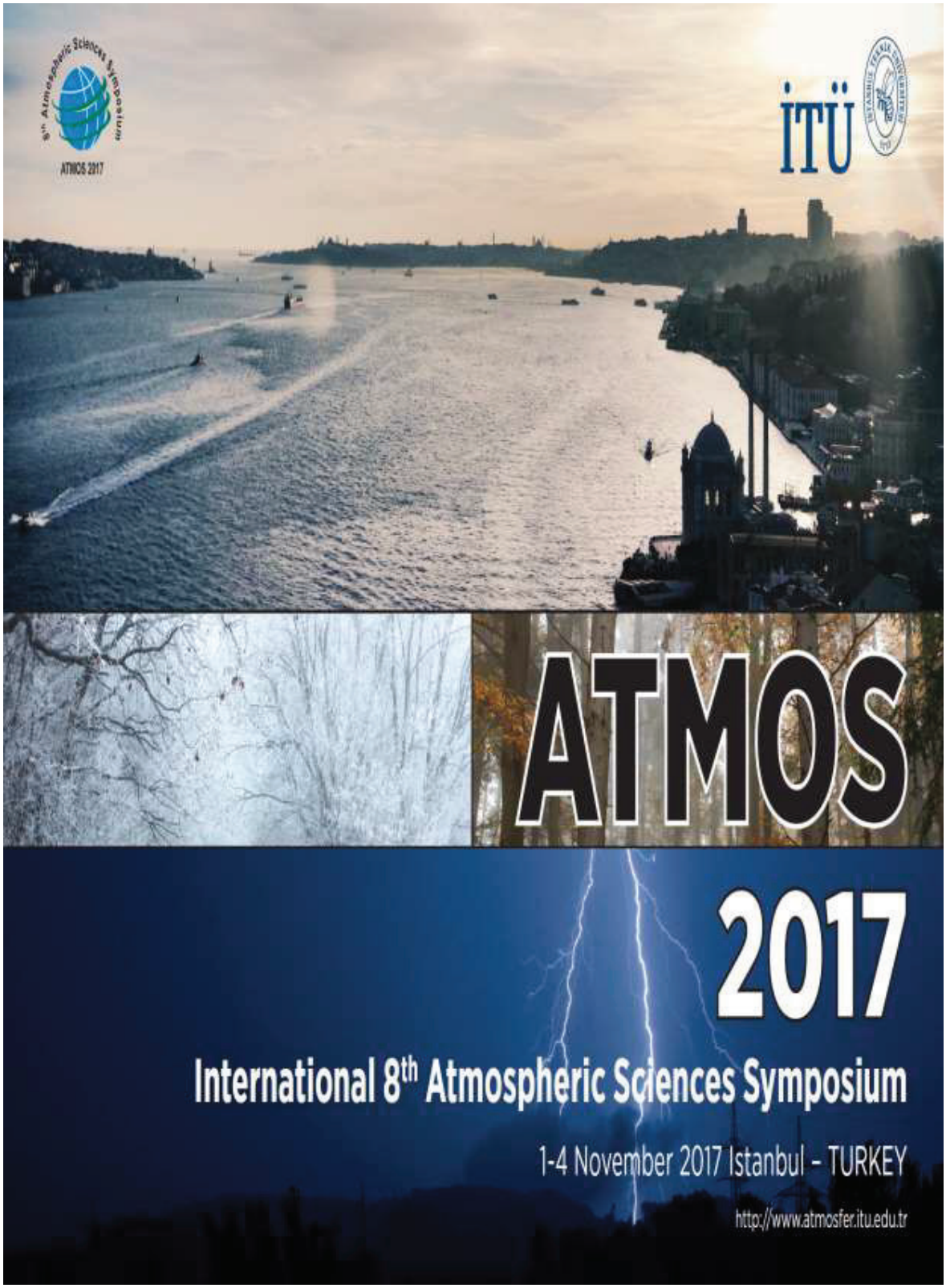
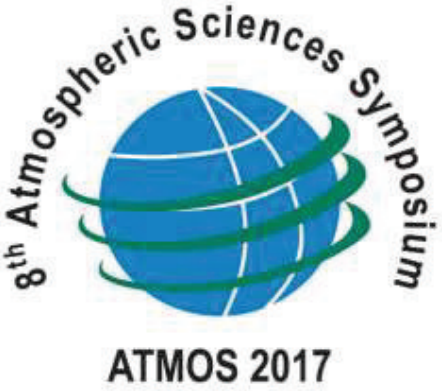

ATMOS
2017
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8th Atmospheric Sciences Symposium
ATMOS 2017

PREFACE

This 8th Atmospheric Sciences Symposium; ATMOS2017 built upon the series that began at Istanbul Technical University, Department of Meteorological Engineering in 1981. Subsequent meetings have been held in 1991; 2003; 2008; 2011; 2013 and 2015 in Istanbul, Turkey.

And it is not just enough to produce scientific data for people but it is also necessary to process the data and share the results of those data as a source for students and a starting point for all researchers, users and policy makers, it is a treasure for mankind.

We are very greatful and thankful to all the valuable researchers, session chairs and all participants who have contributed to ATMOS2017 from all around the world, whose valuable contributions made this event possible.

This e-Proceedings present a collection of 112 papers presented at the Symposium. The main themes covered in the Symposium include;

Agricultural and Forest Meteorology
Air Pollution and Modeling
Air Quality and Modeling
Air-Sea Interactions
Atmospheric Boundary Layer
Atmospheric Dynamics
Atmospheric Environment
Atmospheric Physics
Atmospheric Radiation
Aviation Meteorology
Biometeorology, Medical Meteorology
Causes of Climate Change
Chaos and Non-Linear Dynamics
Climate Change Impacts
Climate Change and Modeling
Climatology
Data Analysis
Extreme Weather Events (flood, storm, avalanche, drought …)
Hydrology and Hydrometeorology
Maritime Meteorology
Meteorological Disasters
Micrometeorology, Mesometeorology
Numerical Waether Prediction
Physics of Cloud and Precipitation
Remote Sensing in Atmospheric Sciences
Renewable Energy Sources
Solar and Wind Energy
Stratospheric Ozone
Solar and Climate System Interaction
Transportation Meteorology
Upper Atmosphere, Ionosphere
Magnetospheric Physics
Urbanisation Meteorology
Water Resources and Management
Weather Analysis, Prediction and Modeling

We would like to thank Rectorate of Istanbul Technical University and the Deanship of Faculty of Aeronautics and Astronautics for supporting ATMOS2017. We would like to express our appreciation to Organizing Committee Members, Steering Committee Members and Scientific Committee Members for their precious support. Last but not least we would like to thank Turkish State Meteorological Service, Union of Chambers of Turkish Engineers and Architects; Chamber of Meteorological Engineers for their valuable support.

Editors

Dr. Orhan ŞEN - Dr. Ceyhan KAHYA
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DETERMINING RISK OF THE FOREST FIRES IN ÇANAKKALE VIA GEOGRAPHIC INFORMATION SYSTEMS AND *ANALYTIC HIERARCHY PROCESS*

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ABSTRACT

Forest fires are one of the natural disasters that cause significant loss of life and property in our country as well as all over the world. Forest fires are one of the most important problems of the countries of the great Mediterranean climate (Portugal, Greece, Spain, Italy, France and Turkey in particular). Since Turkey is located in the Mediterranean Basin, a significant part of its forests is threatened by fire. In Turkey, starting from Kahramanmaraş, especially the parts of the 1700 km coastline extending from the Mediterranean Sea basin to the north part of Aegean Sea and 160 km deep constitute a very sensitive area in terms of forest fire danger. More than half of Turkey's forests (58%) are under the threat of forest fire. In this study, the risk analysis of the forest fires in the province of Çanakkale was examined by the Geographic Information Systems (GIS) and *Analytic Hierarchy Process* (AHP). Forest fire is one of the disasters that cause natural and economic losses in Turkey as well as in the whole world. Forecasting areas where forest fires can occur, in other words, forest fire risk analysis is very important for fire prevention. There have been many studies on forest fire risk analysis up to now, but in those studies, the variables involved in the forest fire weather index (FWI) and the physical and human factors affecting the fire have not been considered together. In this study, topographical (elevation, slope, orientation) and human factors (settlement areas, agricultural areas and distance to population and population density) and FWI (temperature, relative humidity, wind speed) were taken into consideration in Çanakkale. To determine the effects of variables on fire risk, the AHP technique was applied and the weight of each variable was determined. Then these variables were combined in a GIS (Arc-GIS 9.3.1 software) environment by the method of weighted overlay and a forest fire risk map was produced. According to the analysis results, there is no area where the risk of forest fires is low. Many significant parts of the forests in Çanakkale are identified as high and very high-risk areas in terms of forest fires. The high and very high-risk areas are seen in the corresponding areas where the pinus brutia and black pine forests and maquis and phrygana seen intensively.

Keywords: *AHP, Çanakkale, Fires, FWI, GIS, Meteorology*

INTRODUCTION

With the increasing population and industrialization, the pressure on the forests has increased to make more use of forest areas around the world, and sometimes has led to disasters. One of these disasters is forest fires. Forest fires are a destructive disaster that affects biodiversity (Carvalho et al., 2011). As in the world, in our country the vast majority of forest fires are the result of human activities, in addition, a very small percentage of fires occurs due to lightning and volcanic movements and other natural phenomena. When we look at the recorded data of the OGM for 2016, 88% of the forest fires are human-induced. It can be determined that 78% of them were caused by "negligence and carelessness" and 10% by "intentionally" fires. Forest fires originating from lightning occurred at 12% (OGM, 2017a). In Turkey, about 12.76 million hectares of the totaling 22.3 million hectares of forests are in 1st and 2nd degree level of fire-

sensitive areas. Approximately 58% of total forests are under the influence of the Mediterranean climate and risk of the forest-fire is very high in those forests. The forest-fire statistics of the last 10 years says that 8903 hectares of forests have been damaged of the 2330 forest fires. Only considering the forest fires occurred in 2016, approximately 9154 hectares of area were damaged due to a number of 3188 forest fires (OGM, 2017a). During those fires, besides the damage of forest areas, serious losses of life and property were occurred (Ertuğrul, 2005).

Forest fires in Turkey are mostly observed in the Aegean, Mediterranean and Marmara regions. Muğla, Antalya, İzmir and Çanakkale cities (study area of this project) are the most dangerous regions in terms of forest fires (DPT, 2001). Due to the very hot and arid weather in the summer months, which is the dominant feature of the Mediterranean climate large areas are damaged due to forest fires, especially in the Aegean and Mediterranean regions. In the Mediterranean and Aegean regions, forest areas of 0-400 meters above sea level are within the first vulnerable zone of the forest-fire. The maquis and red-eyed stalks in these forest areas are damaged due to settlement, agriculture and tourism activities of human (OGM, 2008). Majority parts of the forests of Çanakkale Regional Directorate of Forestry (CRDF) are in the first and second sensitive areas in terms of forest-fire. When the fire-sensitive areas in the CRDF are examined, the forests of Çanakkale, Keşan, Ayvacık and Bayramic are at the first sensitive level. On the other hand, the forests of Biga, Çan, Yenice and Kalkan are in the second degree. In addition, there are no third, fourth and fifth degree sensitive areas in the CRDF (Türkeş ve Altan, 2012). The study area of Çanakkale province is one of the forest-rich areas of the country in terms of forest assets. There are 2 national parks named Gelibolu Peninsula and Troy Historical National Parks. However, as mentioned above, the province is a priority place both in terms of forest fires and in the degree of fire sensitivity. Therefore, the aim of this study is to elaborate the risk of forest fires in this area and to identify a risk-map.

Prediction of forest fires is very difficult due to the complexity of forest fires as well as the effects of human factors. However, with the help of fire information systems and fire risk mapping tools, it may be possible to reduce most of the damage caused by fires (Erten et al., 2005). Though it is unlikely to completely prevent forest fires, the risk analysis may provide support for decision-makers for taking preventive and fire-fighting activities. As a matter of fact, the number of studies carried out in recent years in order to benefit from the results of risk analyzes on disasters both in the world and in the country, has increased considerably. Comprehensive studies have been undertaken in order to reveal the risk of forest fires, especially in forest fire sensitive countries, and various models have been proposed. For example, in the United States and Canada two models were developed for the "forest fires hazard rate system" in 1964, then in 1972 this number increased to nine. In 1978, the number of models reached 20 (Deeming et al., 1978). In a study by Hayes (1944), a "firefighting index" was developed, taking altitude and daylight hours into consideration. Van Wagner (1974) developed an index called "Canada forest fire weather index" and is currently implemented in Canada. Cheney (1976) examined the statistical distributions of forest fires in the period covering 1973-1974 in Izmit, Muğla and Antalya and created a daily fire "danger class" for July, August and September.

In recent studies, remote sensing tools and Geographic Information Systems (GIS) techniques have been used effectively. For example, Jaiswall et al. (2002) prepared maps of forest fire risk-sites for the Gorna basin in India using satellite imagery and GIS technology. Yin et al. (2004) have created forest fires risk zones using GIS in Hinngan Mountain, which is one of the mountainous areas in China. Chandra (2005) have developed "forest fire risk maps" using GIS and remote sensing (RS) methods in the Uttaranchal region of India. Erten et al. (2005) have

created a "forest fire risk map" for some of the Gallipoli Peninsula, using RS and GIS methods. Pradhan et al. (2007) have examined the forest fire sensitivity of the Kuala Lumpur environment in Malaysia using RS and GIS. Small et al. (2007) have applied GIS techniques in Korudağ Forestry area in Turkey, and they have revealed fire behavior depending on the characteristics of flammable substance types and weather conditions. Saglam et al. (2008) have identified forest fires in the forest area of Korudağ. Assaker et al. (2012) have analyzed the risk of forest fires in the Nahr Ibrahim Basin in Lebanon using RS and GIS. Sringeswara et al. (2012) have prepared a forest fire risk map and forest fire management plan for Kudremukh National Park in India. Karabulut et al. (2013) have determined the risk of fire in the Başkonuş Mountain (Kahramanmaraş) in Turkey by GIS. In a significant part of the studies, fire risk analyzes were carried out in different countries by using GIS and applying weighted cointegration method. To determine the risk of fire in these studies, it is generally necessary to determine slope, elevation, view, plant type, plant density, distance to settlement, distance to electric power lines, distance to agricultural areas and land use. In some studies, only a few meteorological data such as monthly rainfall, temperature change, sunshine duration and evaporation have been included in the analysis. However, meteorological parameters such as temperature, precipitation, relative humidity, wind speed and direction have important effects on the occurring and spreading of the wildland forest fires (Byram, 1954, Countryman, 1971, Ryan, 1977; Tatli, 2014).

On the other hand, according to the open literature, it was seen that "forest fire weather indexes" did not participate in the calculation of forest fire risk analyzes in Turkey. It is of great importance to participate in assessing meteorological parameters along with the constants such as "slope, elevation, distance to the settlement area and land use" in order to better evaluate wildland forest fires. These topics have been extensively investigated in this study.

DATA AND METHODOLOGY

Study Area

The province of Çanakkale is located in the South Marmara Region (Figure 1). The city's territory lies between 27°35' - 27°45'E longitudes and 19°30' - 40°45' N latitudes. The total surface area of Çanakkale which is composed of Biga and Gelibolu Peninsulas being 9737 km^2. Çanakkale is surrounded by Balikesir from east and south, Aegean Sea from the west, Edirne from the northwest and Tekirdağ and Marmara Sea from the north.

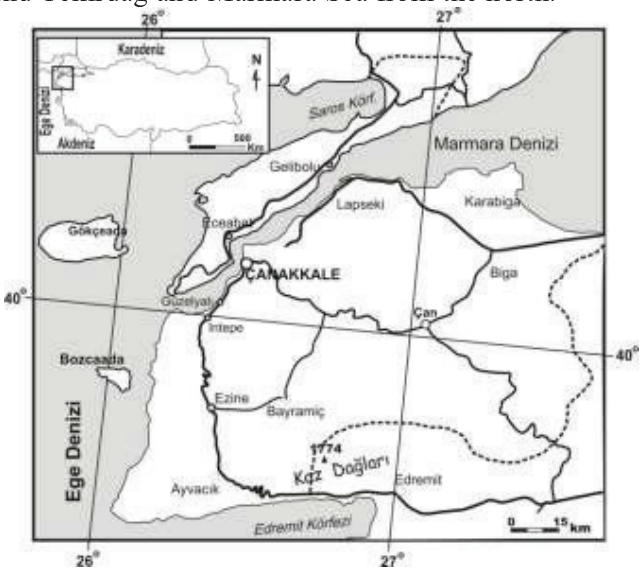


Figure 1. Location map of Çanakkale

There are different geological units formed in different periods. Çanakkale and its surroundings began to form on the Mesozoic rocks in the Paleotectonic period and continued to develop as sedimentation area in the Upper Cretaceous period. The present marine features have taken place in terrestrial features after the formation of the Biga and Yeniköy volcanic in the late Oligocene and early Miocene periods due to volcanic activity at Eocene (Erol, 1992; Türkeş, 2007). Çanakkale is a complex geological and geomorphological point of view. The most important geomorphological unit is undoubtedly the Kaz Mountains located in the peninsula of Biga. These mountains are the most important morphological unit of Biga Peninsula with a height of 1774 meters (Akbulak, 2010). The highest mountain on Gallipoli is Mount Koru (726 m). The lowlands located in the peninsula are Kavak, Cumalı, Yalova, Kilye, Eceabat and Piren. The other plains in the Biga peninsula are Ezine, Bayramic, Kumkale, Biga and Karabiga, Yenice, Kalkım, Umurbey and Sarıçay. Çanakkale, located in the south Marmara division has a local Marmara transition climate (Turkes, 2010).

The effects of polar and Tropical systems and the interaction of north-south air movements, different pressure generations have been observed in different periods. For example, terrestrial Tropical (cT) and marine Tropical (mT) air masses are dominant in summer, while terrestrial Polar (cP) and marine Polar (mP) air masses are more frequently observed in winter (Koç, 2001). In Çanakkale, the rainfall tends to decrease from south to north, and from coast line to interior areas. In general, transition-climate characteristics are observed in the field. The marine impact in the region is decreasing from the coast to the interior. The hottest and driest month is August. Due to the lack of precipitation and the evaporation-excess, August differs from other months in terms of drought. This explains why forest fires are frequently seen in this month. The current dominant directions are the north-northeastern (NNE) and northeastern (NE) winds. The dominant wind is due to the pressure systems of polar. After the northern winds, the second most important winds are the southern winds. The most effective winds in the area are easterly and South-westerly winds. In fact, the wind is not so effective in the beginning of the fire, but it is great importance during the growth and spread of the fire. Since Çanakkale is located between the Mediterranean and Euro-Siberia (Öksin) phytogeographical regions, he has transition characteristics of vegetation cover. That is, the Blacksea phyto-geography area being inhabited to the northern parts of the Kaz Mountains, the area to the south of the Blacksea phytogeographical region dominates the features of the Mediterranean phyto-geography. In some places, the forests seem to have risen after raising more than 150-200m, although they started just right by the coastal areas. Due to ascent, there are wrinkled plants with features of steppe (Kantarci, 1996). On the north-facing slopes of the study area, there are oak species in the areas where the red-headed, larch and forested areas are damaged, as well as alder (Alnus), Ihlamur (Tilia), and chestnut (Castanea) forests. There are also Pinus pinea, Maquie and Garig Juniper, Pinus nigra and Abies in the Mediterranean phytogeography area.

GIS Database

To check the validity of the proposed methods for forest fire risk analysis, the data set must be complete and accurate. In this context, a 1/25000 scale topographic map of the study area was produced using the maps from the cartography laboratory in the Geography Department of Çanakkale Onsekiz Mart University. The digital elevation model, slope and elevation maps were produced in a similar way. The meteorological data set used to calculate the Canadian Forest Fire Index (CFWI) was provided by the Türkish State of Meteorology. The Landsat (L8 OLI / TIRS) satellite images of November 18, 2016 were used to determine the NDVI values indicating the vegetation density classes of the study area. Current stand maps showing the distribution and closure of plant species were obtained from Çanakkale Forest Regional Directorate. The data related to the land use situation was obtained from Çanakkale 2012-

CORINE data base and numerical stand maps. In order to determine the population density of the settlements, the data of 2016 of the address-based population registration system (ADNKS) of the statistical institution of Turkey (TUIK) was used. The distribution of highways was obtained from the digital road data of the cartography laboratory in the Geography Department of Çanakkale Onsekiz Mart University, the data showing the start points of fires in 2007-2016 with coordinates were obtained from the Çanakkale Forest Regional Directorate.

Methodology

The GIS approach provides the opportunity for cheap, fast and error-free analysis of forest fires during the monitoring of the occurrence of the fires and subsequent damage (Erten *et al*., 2005). Because of these advantages, GIS is used as a very effective tool for forest fire risk analysis. Many physical and human factors were evaluated together in risk analysis. Of these, calculation steps the values of CFWI in Figure 2. The source code of the CFWI was written in FORTRAN 2003. Another component NDVI was obtained by using the images of the Landsat (L8 OLI / TIRS) satellite and they were classified in terms of vegetation density to form NDVI layer. In addition, the type of variables used in the risk analysis was selected by consideration the knowledge of literature and expert opinions (experts of the project team and Çanakkale Forest District Directorate Forest Fighting Branch Directorate). Considering the geographical conditions of the study area, the variables used in the study are slope, elevation, aspect, vegetation type, plant-cover (closure of the pavement), distance to previous-fire exit, distance to road, settlement areas and agricultural areas, population density and the values of CFWI as given in Table 1.

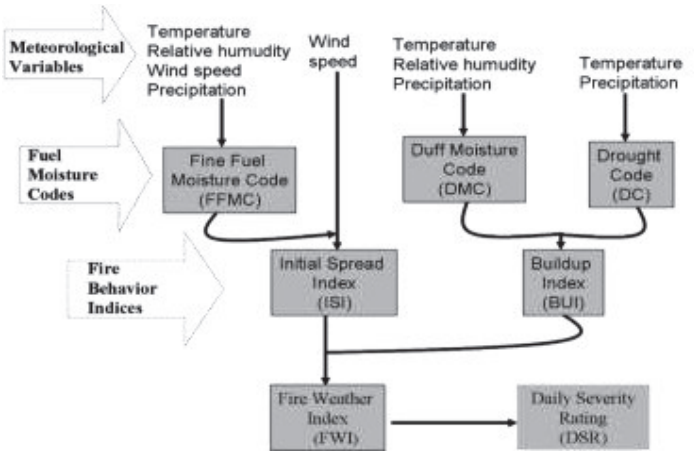


Figure 2. Canadian forest fire weather index system and its components (after Turner and Lawson, 1978)

To complete the necessary missing data and to generate data at the new grid points, a well-known geo-statistical model (Tatli and Dales, 2016) named kriging was used. The slope, elevation and elevation layers are produced from the Digital Elevation Model used in GIS. In order to be able to create a distance layer between the settlements, the point centres of the province centre, the districts and the villages were used.

In the study, the Analytical Hierarchy Process (AHS) method, one of the "Multi Criteria Decision Making" techniques (MCDM), was applied to determine the importance of each component in the fire risk formation (due the restriction of number of papers the details of AHP method were not given here). Within the scope of the study, a total of 12 variables were evaluated in the formation of forest fire risk. It is recommended that the number of variables should not exceed 9 to make the right decision while weighing by the AHS method (Saaty,

1980). For this reason, the 12 variables seen Table 1 were taken into consideration and divided into subgroups, so that the scores of the main variables and sub-variables could be separately determined. After determining the weights of the main and sub variables by the AHS method, the layers in the raster format of the corresponding variables were combined by weighted over layering method (considering the weights of the variables) in the GIS environment.

Table 1. The major and sub-variables used in the study

Main Variable	**Sub-Variable**
CFWI	--
Previous fires	--
Topography	Slope
	Altitude
	Aspect
Vegetation	Plant type
	Plant coverage
	NDVI
Human Factors	Population density
	Distance to settlement
	Distance to road
	Distance to agricultural

RESULTS

The forest fires in Turkey arise mainly due to human reasons, on the other hand topography, meteorological conditions and characteristics of the flammable material are also effective in formation of the fires (Altan and Turkes, 2011, Neyişçi et al., 1999). The "altitude steps" shown in Table 2 were divided into 9 classes with a maximum of 10 score point.

Table 2. Risk score according to altitude

Altitude (meter)	**Risk score**
0 - 200	10
201 - 400	9
401 - 600	8
601 - 800	7
801 - 1000	6
1001 - 1200	4
1201 - 1400	3
1401 - 1600	2
1600 +	1

Since the altitude values are low throughout the city, the high-risk of the fire category is so common. As given in Figure 3, it is observed that the scores are high in the coastal areas and low in the mountainous areas. The low risk scores are seen in the Ida Mountains and its surrounding, which is the highest part of the region.

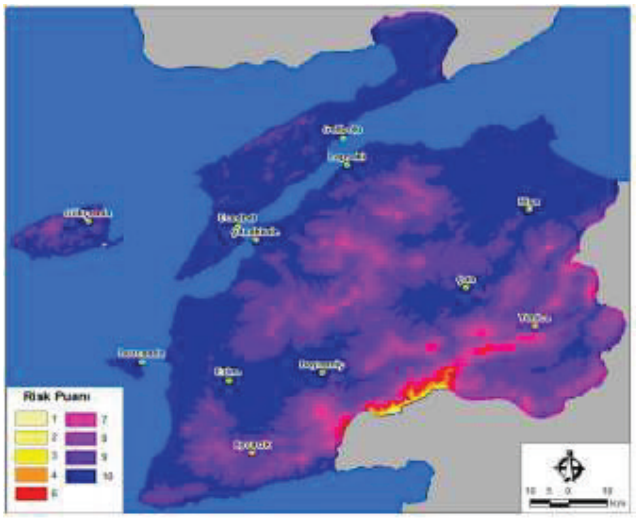


Figure 3. Risk scores according to the altitude

The slope is another important factor in the spread of fire as it affects the rate of accumulation of the flammable material (Bilgili, 2014; Başaran et al., 2004). The slope values were divided into 6 classes and the risk scores ranging from 1 to 10 assigned (the results are not given here due to the limitation of the number of pages). The "aspect" that affects the duration of sunshine and humidity was accounted in the risk analysis. Similarly, the aspect that affects the moisture content and temperature of the flammable material also determines the behaviour of the fire (OGM, 2017). In the study area, the aspect was divided into the classes shown in Table 3, and scores ranging from 1 to 10 are given. Especially the risk of fire is high on the southern slopes of mountainous and plateau areas (Figure 4).

Table 3. Risk scores according to aspect

Aspect	**Risk score**
Flat	5
North	1
Northeast	2
East	5
Southeast	7
South	10
Southwest	8
West	5
Northwest	2

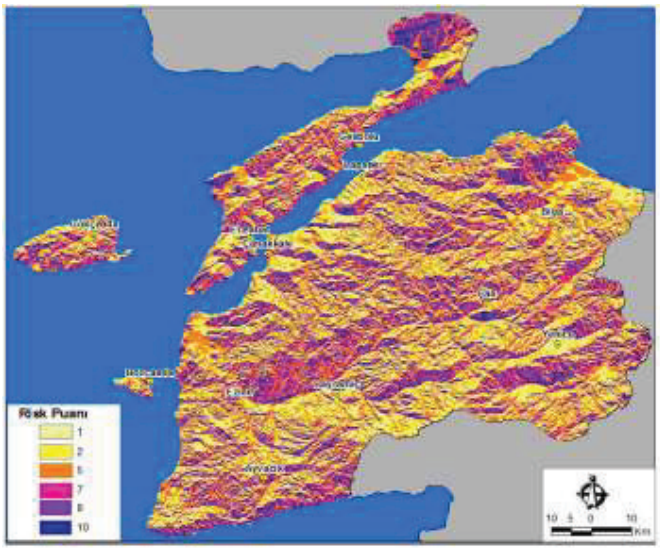


Figure 4. Risk scores according to aspect

The CFWI values have been included in the analysis in order to evaluate the effect of meteorological conditions on the forest fires. It is well-known that meteorological variables are very effective on the fire behaviour and spread of it (Başaran et al., 2004; OGM, 2008, Türkeş and Altan, 2012). Since Çanakkale experiences semi-arid Mediterranean climate features, the evaporation and precipitation values have balanced distribution (Tatli et al., 2004, 2005, Turkes and Tatli, 2011; Tatli and Turkes, 2014; Tatli, 2015). However, in some years, especially during the summer season, the water shortage reaches the drought level causes forest fires. The CFWI values have mainly "high" and "very high" risk throughout the region. However, in order to obtain a more pronounced meteorological pattern with a local-sense, the CFWI values were converted between 4 and 10 scores, and the map of the new scores is shown in Figure 5. Considering this figure, the CFWI pattern shows a gradient of decreasing risk from Bozcada and Gökçeada to northwest and east of the interesting area. Especially in the coastal areas, the risk seems to be significantly higher than the inner regions due to elevation of the inner areas. The fire risk observed around Gökçeada, Bozcada and Gelibolu Peninsula and Ezine is quite high. One of the reasons for the high fire risk values seen in these areas may be that the effect of hot-winds blowing from the Aegean Sea.

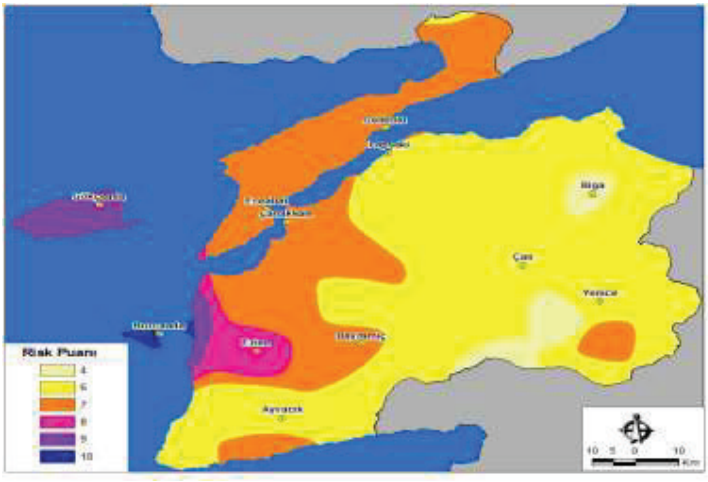


Figure 5. The risk pattern of the forest fire weather index

On the other hand, because of the limitation of the number of pages, the details of the risk analysis for the other variables given in Table 1 such as "vegetation cover", "plant type", "NDVI", "distance to settlement area", "distance to road", "population density" and "distance to the start points of previous fire occurred" were combined in order to obtain the risk map shown in Figure 6. The marginal risk maps of each component were not given here due to the number page limitation. The score of the risk values were classified as given Table 4. Accordingly, it is seen that the risk in Çanakkale province is quite high. There is no area where forest fire risk is low. A few moderately risky areas are observed in some narrow areas.

Table 4. Classification of the risk of forest fires in Çanakkale (in %)

State of risk	Area (ha)	Ratio (%)
Moderate	2549	0.53
High	153.317	32.13
Very high	302.802	63.46
Extreme	18.457	3.87
Total	**477.125**	**100**

The final risk map is given in Figure 6. According to this map, the high-risk and very high-risk areas are dominant. The high-risk areas are mostly concentrated around the Ida Mountains located in the south-east of the province, while high-risk areas are also found in the central areas. There are also high-risk areas in the area between Gelibolu Peninsula and Eceabat-Gelibolu. The part of the Ida Mountains, Ayvacık and Ezine-Canakkale lines are found in very high-risk areas. Gökçeada is another area where forest fire risk is very high. Similarly, there are areas in the Eceabat-Gelibolu line with very high risk. A few extremely high risk areas are seen on the edge points of Gökçeada, Bozcaada, Ida Mountains and its surrounding, Eceabat-Gelibolu line (Figure 6).

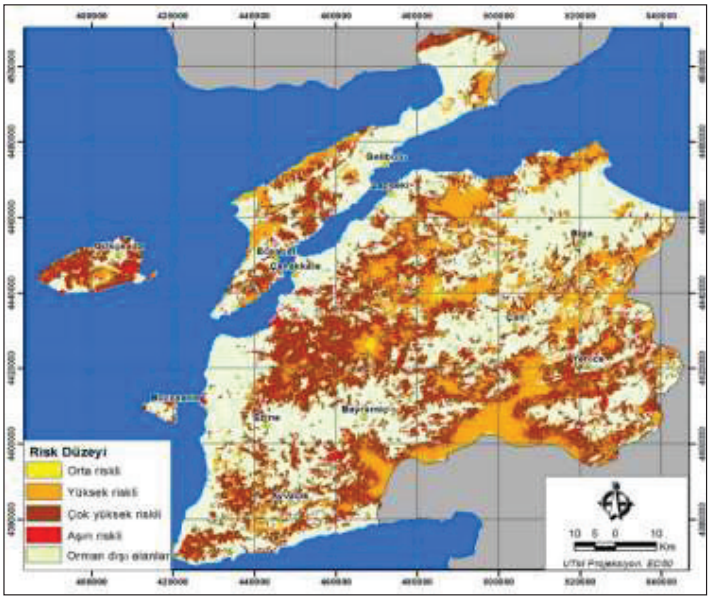


Figure 6. The risk map of fires over Çanakkale

CONCLUSIONS

In the risk analysis of predicting the areas where fires can occur is of great importance in combating forest-fires and preventing. The risk of forest fire of Çanakkale was carried out with the integration of remote sensing, GIS and AHP methods. The risk map was obtained by

merging the sensitive areas in a most accurate way. For example, the expert-knowledge was also utilized in order to calculate the risk situation. In study, the topography, vegetation and human factors, CFWI and distance to the starting points of previous fires were used as the main variables. However, the slope, altitude and aspect conditions were considered as the sub-variables of topography. Similarly, plant type, plant cover and NDVI variables were considered under the vegetation variable. Likewise, the population density, distance to road, residential areas and agricultural areas were taken as sub-variables of the human factor.

According to the fire risk map, it is seen that the risk of forest fire is quite high. There is no area with low risk. The medium risk areas are spreading in a very narrow area, especially, existing in the small spots around Çan. The high-risk areas are concentrated around the Ida Mountains located in the south-eastern part of the province. Moreover, there are high-risk areas in the area between Gallipoli and Eceabat-Gallipoli. It has been determined that there are very high-risk areas in Ida Mountains, Ayvacık-Ezine-Canakkale line and Gökçeada. According to high and very high-risk areas, extreme risk areas are located in the south of Gökçeada, in Bozcaada, around Ida Mountains and between Eceabat and Gelibolu line.

It is revealed that there are too many high and very high-risk areas in terms of forest fire in the province and that protective and preventive measures should be given much importance in the fight against fire in the region. It is suggested that the findings obtained should be taken into consideration in the possible management plans that can be formed within the fight against fire in Çanakkale province. In areas where fire risk is high, it may be planned to clean roadsides to reduce the load of combustible materials, to make regulations on the use of recreational areas, and to determine the rules to be followed by local people and to make necessary informed consent. It should also take advantage of risk maps to take a variety of preventive measures, such as training that will be useful in the fight against fire, planning fire safety roads and lanes, reducing the amount of flammable materials, identifying locations for placement of combat equipment, and construction of surveillance towers. Extinguishing vehicles, which have the ability to intervene quickly and effectively in fighting against fires, such as airplanes and helicopters, must be deployed at points that can reach high risk areas in a short time. Because fires that may occur in such areas may cause serious loss of life and property due to the severity of the fire, in this context, both the fire frequency and the burning area can be greatly reduced by precautionary trials. The study shows that the combined use of GIS, RS and AHP methods in forest fire risk analysis can produce positive results. Consequently, the application of the suggested method in other areas will also benefit from the investigation of its validity. It is thought that more accurate, effective and successful results can be obtained by taking into consideration the current data which can be converted into useful, fast and desired formations obtained from these types of studies, especially in decision stages to be taken within the scope of forest fire fighting activities.

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