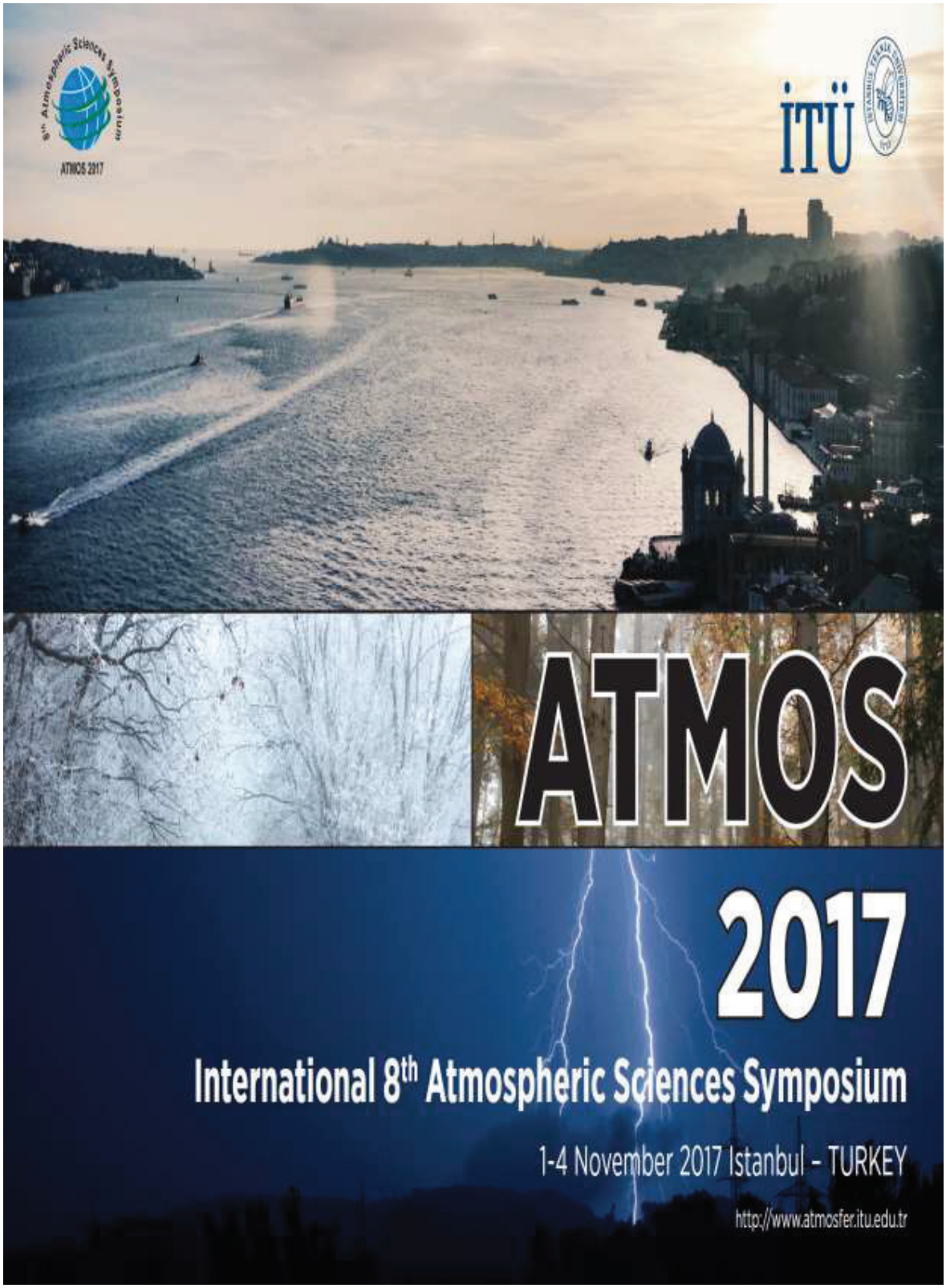
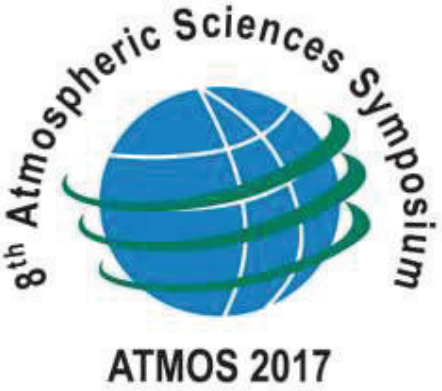

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8th Atmospheric Sciences Symposium
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PREFACE

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
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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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INVESTIGATION OF CANAKKALE FOREST FIRES BY CANADIAN FOREST FIRE WEATHER INDEX

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ABSTRACT

In this study, the Canadian Forest Fire Weather Index (FWI), an index of which has been effectively used, was applied for the investigation of the wildland forest fires in Çanakkale. Because the area of Çanakkale is in the region of subtropical Mediterranean climate, it is arid in summer and semi-humid in the other seasons. Due to the geographical features of Çanakkale, forest fires here are very likely to occur and spread. Forest is an important component of both natural resource and ecosystem. Forests have become an important resource for humans throughout history, as well as being a ecological domain for many animal breeding and feeding. Forest fires, one of the most important causes of destruction of forests, are due to natural and human factors. Although the share of human activities in the beginning of the fires is high, the natural factors "meteorological and the conditions of the tree species, etc." are the most fundamental factors affecting the behavior and development of these fires. The FWI is an index expressed as a simple number for explaining and understanding the very complicated forest fire risk. This method, which accounts the factors that make up the forest fire, is basically composed of three main components. These include: i) meteorological conditions, ii) combustible material moisture codes, and iii) fire behavior index. Compared with the statistics of the past forest fires seen in Çanakkale, the results show that FWI can predict the forest fire risk for Çanakkale quite efficiently.

Keywords: *Çanakkale, Forest Fire, FWI, Meteorology, Risk*

INTRODUCTION

Forests are the vital natural resource for conservation of natural balance and sustainability of life. Those creatures of forests are both a source of life and a natural habitat which create ecosystem. It is also one of the important sources that have been actively utilized by people since ancient times (e.g., Akbulak and Özdemir, 2008). Forest fires, if the physical conditions are ready, often start with human factors, but some may be due to lightning.

Throughout the history, forests have become under the constant pressure of farmers to open more agricultural land, for industrial raw materials, or for human influences such as domestic fuel demand. In addition, forests have been constantly threatened by natural causes such as mass movements or climate change-induced drought. When the statistics of forest fires from 2010 to 2015 has been examined, one can see that a total of 35,227 issues of forest fires have occurred and 145631 hectares of forest areas have disappeared in these fires. It is seen that 3738 of these fires were due to intentional consequences, 17776 of them resulted in negligence-accident, 3916 of them were caused by natural causes (lightning etc.) and 9797 of them were due to the unsolved reasons (General Directorate of Forestry. OGM, 2015). Along with the rapid development of the technology, a early warning systems in which, satellite and meteorological forecasting data (calculating various forest fire weather indexes etc.) used together might give a great advantage in combating forest fires and its losses being minimized (e.g., Akbulak, 2010; Bouabdellah et al., 2013).

In many countries of the world (especially in wild-forest fires) intervention can be achieved without fire or fire-growth. In particular, very successful results have been achieved in many countries, especially in Canada, the USA and Australia. To give an example, this success rate is 90% in Canada (Ertuğrul, 2005). Hefeeda *et al*. (2007) used a Fire Weather Index (FWI) as an indicator in early warning systems they developed. They found the FWI approach widely used in many countries, such as Canada and the USA, provided very successful results. Dimitrakopoulos et al. (2011) found that the Canadian Forest Fire Index (CFWI) gave very good results on behalf of the eastern Mediterranean wildfire early warning system.

For a closer look at Australian wildland forest fire, Dowdy et al. (2009) compared the "McArthur Forest Fire Hazard Index (MFFHI)" with "CFWI." The comparison shows that the McArthur index is much more sensitive to temperature and relative humidity than the CFWI. On the other hand, the result of the study suggests that for Australia, both indexes would be much more successful if used together. For a closer look at the wildfire fires in Australia, Dowdy et al. (2009) have compared the "McArthur Forest Fire Danger Index (MFDI)" with CFWI. As a result, they found MFDI been much more sensitive to temperature and relative humidity than the CFWI, while CFWI been so sensitive to wind speed and amount of the precipitation. They suggested that better results could be obtained if both indices were used together in the early warning system of wildfire fires in Australia. Along with morphological and human structure variables, meteorological variables have an important influence on the wildland forest fires and behaviour patterns. Taking this into consideration, the FWI has more advantages because it is derived from meteorological variables unlike many other methods (Tian et al., 2011; Author, 2014).

In this study, it was aimed to set up a risk map of forest fires in Çanakkale with CFWI. After the Introduction section given above, the "data and methodology" section of the study is given in the second section. The third and fourth chapters cover "results" and "conclusions", respectively.

DATA AND METHODOLOGY

Data and Study Area

To show the validity of forest fire risk analysis, it is necessary to collect effective data as it relates to the validity and adequacy of the data obtained. For this purpose, the daily data from meteorological stations of Balıkesir, Bandırma, Biga, Bozcaada, Burhaniye, Çanakkale, Edremit, Enez, Erdek, Ezine, Gelibolu, Gökçeada, Gönen, Keşan, Malkara, Manyas, Savaştepe, Susurluk, Şarköy were used. This data set was obtained from the Turkish State of Meteorology (TSM). The data used in these stations are the total daily precipitation and maximum temperature, wind speed and relative humidity measured at 14:00 GMT, respectively.

The data used in the study are daily-scale data from 1970 to 2015. In addition to the stations listed above to calculate the CFWI, the missing points in the mountainous areas have been estimated by the means of spatial interpolation technique. The geostatistical method called Kriging was applied to complete data or gridding (Tatli and Dalfes, 2016).

In this study, the estimated values of temperature and wind at the grid points are obtained using the data of nearby stations in the vicinity so that the effect of changes that can be caused by the influence of the topography can be evaluated in this way.
During the application the Kriging method to the temperature data, the vertical temperature gradient was taken as 0.65 ° C / 100 meters. On the other hand, for interpolation of the relative humidity values, the data in the neighbours were not used. First, the dew point temperatures

(T_d) were found for each station, then these T_d values were interpolated to the grids by the Kriging method. Using the interpolated dew point temperatures, the actual vapor pressures and temperatures were used to obtain saturated vapor pressure values. At last, the relative humidity values were calculated from the ratio of these vapor pressures. Thus, the dew point and current temperature values of the topography effect were indirectly transferred to the gridded relative humidity values. All calculations were performed using an enhanced FORTRAN 2003 source code program and the maps obtained using by GIS program of the Arc-GIS 10.3 version.

The Çanakkale province is in the South Marmara Division of the Marmara Region. Its geographical position is between 27 ° 35'-27 ° 45'E longitudes and 39 ° 30'-40 ° 45' N latitudes and its surface area is about 9737 km^2. The Aegean Sea lies in the western part of the province, Edirne in the north part, Tekirdağ and Marmara Sea in the north, and Balikesir in the eastern and southern part. Çanakkale, including the central district, is made up of 12 districts and 568 villages.

The Ida (Kaz) Mountains in the southern part of the study area rise immediately after the coast and peak at 1774 meters on the Biga peninsula. The Ida Mountains and its surroundings has a form of steep slopes and deep valleys due to the influence of the rivers. The northern sections and the coastal areas of the study area are a slightly rugged appearance broken by rivers (Türkeş, 2007).

Despite it belongs to macro Mediterranean climate zone, Çanakkale has local-climatic features of Marmara region, which is locally distinctive characteristic and shows a transition climate between local Mediterranean and Black Seas. The seasonal rainfall and temperature distributions are different according to the macro Mediterranean climate (Turkes, 2010, Altan and Turkes, 2014). The Ida Mountain in the district behaves as a barrier to the seasonal air blowing from tropics and polar, subjecting these air masses rising along the mountain slopes, and to occur the orographic precipitation. This situation distinguishes the features from the characteristic macro-Mediterranean climate in terms of temperature and precipitation within the year (Turkes and Tatli, 2011; Turkes and Altan, 2008).

Çanakkale is one of the most forested provinces of Turkey with 54% of the province's overall forest cover. Due to the "summer drought" which is the main feature of Çanakkale's climate, there is a marked water-shortage from July to the end of October during the year (Altan and Turkes, 2011). In Çanakkale province, due to the meteorological variability and the topographical changes in a narrow area of the region, the variety of plant species is very helpful in terms of diversity and density, and in fact there are about 800 different plant species seen in the Ida Mountains, around 80 of which are endemic (Altan and Turkes, 2014).

In the period of seen in Figure 1 of the water budget of Çanakkale province, in the "fire season", the possibility of fire is high and the area of violence and influence can be wider. As seen in this figure, the water shortage is beginning from the beginning of July, with excess water accumulating during the winter with decreasing precipitation towards the end of April. Convective precipitations, which sometimes occur in the summer months, are not affected much in the prevention of summer drought because of short time and small amount of rainfall. The rains, which started from the beginning of October, can only return to the water-surplus conditions after mid-November with the reason of water-deficiency during the summer.

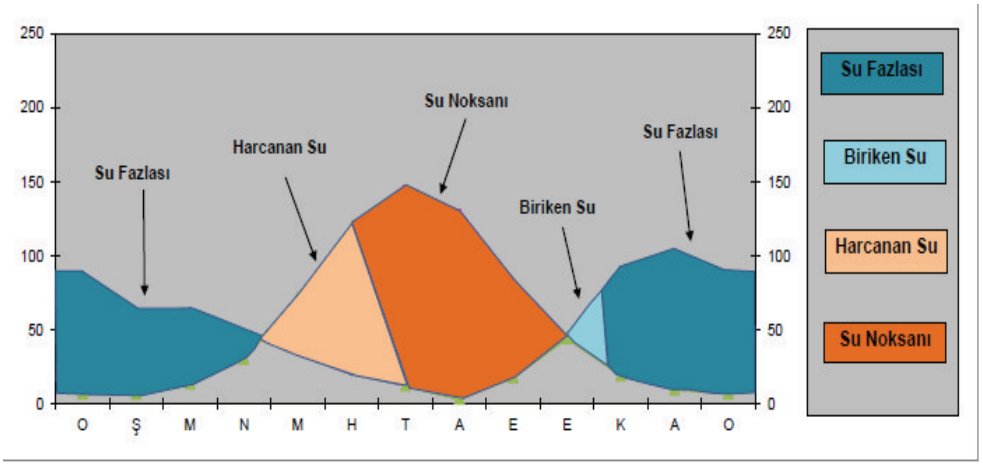


Figure 1. The annual water budget of Çanakkale

Methodology

The FWI is an index that has been used successfully in many parts of the world, combining the meteorological information with the combustible material on the surface (Van Wagner, 1974; Turner and Lawson, 1978; Lee et al., 2002; Sharples et al., 2009; Matthews, 2009) ; Dowdy et al., 2010; Clarke et al., 2013, Author, 2014; Camia et al., 2017). One of the main reasons for using this index is to estimate the forest fire formation, which is defined as highly complex, with a simple number in the potential sense.

In a study of Yamakin (2006), many fire hazard indexes using in many countries were compared by a software program named "fire danger processing" and test of "Mandallaz and Ye's Performance Score" method. Among the many fire hazard indexes evaluated according to the test results, CFWI was chosen as the "forest fire hazard index", as a good representation for Turkey and other Mediterranean countries. Because CFWI is used in this study, the formulas and algorithm are quite long and only the calculation steps describing the underlying logic are given in Figure 2. As seen from this figure; CFWI calculations involve meteorological conditions such as temperature, precipitation, relative humidity, wind speed and dew point temperature.

In Mediterranean countries, during the day, the most likely outbreak of forest fire is at 14:00 GMT (after lunch). Because the maximum temperature and the saturated vapor pressure take the greatest value at this time. Since humidity in atmosphere and in flammable material reaches its minimum value (dryness is the most) at this time, the possibility of a fire occurrence or the risk is very high. Combining meteorological observations with flammable material moisture, CFWI is obtained by integrating the Initial Spread Index (ISI) and Build Up Index (BUI), which describe fire behaviour.

According to the algorithm of Van Wagner (1987) given in the flow chart below (Figure 2), the daily FWI calculations were made for each station. There is no an obvious fire-meteorology pattern for the region in the normal literary sense because the entire region is in the "Very High" and "High" risk classes. However, the changes in topographic patterns and local seasonal recurrence of meteorological airflow should be accounted. From these concerns, it was again divided into categorical classes, so that a distinct fire-meteorology pattern would emerge. All calculations were done with the help of a program developed in FORTRAN 2003.

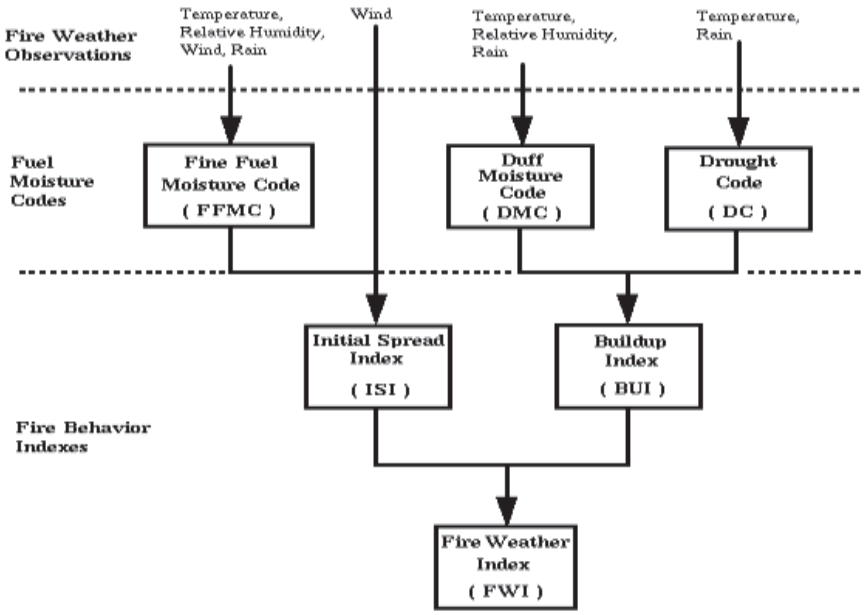


Figure 2. Canadian Fire Weather Index (CFWI) System and its components (modified from Van Wagner, 1987).

The evaluation of the CFWI components given above in Figure 2 is summarized in Table 1. DSR , which is the abbreviation given in this table, means "Daily Severity Rating", the meanings of other abbreviations are given in Figure 2.

According to Table 1, because the DSR values over Çanakkale are almost "High" and "Extremely High", the CFWI values divided into six classes again (mentioned just before) to display a definite fire-meteorology pattern. The "fire risk map" given in the Results section of the manuscript is drawn from this point of view Table 1.

Table 1. Danger classes of Canadian forest fire weather index

Index	Low	Moderate	High	Very High	Extreme
FFMC	0 - 80.9	81 - 87.9	88 - 90.4	90.5 - 92.4	92.5+
DMC	0 - 12.9	13 - 27.9	28 - 41.9	42 - 62.9	63+
DC	0 - 79.9	80 - 209.9	210 - 273.9	274 - 359.9	360+
ISI	0 - 3.9	4 - 7.9	8 - 10.9	11 - 18.9	19+
BUI	0 - 18.9	19 - 33.9	34 - 53.9	54 - 76.9	77+
DSR	0 - 0.47	0.48 - 2.91	2.92 - 5.96	5.97-13.25	13.26+

RESULTS

In this study, the effects of meteorological factors on forest fires were analyzed using CFWI method. In the analysis of CFWI, temperature, precipitation, wind and relative humidity were taken from meteorological variables. These variables used in the FWI have significant effects on the behavior and growth rate of forest fires in the wildland (Wagner, 1987, Altan et al., 2011, Altan and Turkes, 2011, Sweet and Turkes, 2014).

The meteorological variables used to calculate CFWI are temperature, wind speed, precipitation and relative humidity. The effect of these variables on the occurrence of forest fires can be measured in the drying and humidification of the burning material in the forest, that is, if these

meteorological variables are in proper conditions, the risk of ignition of the fuel increases (Altan and Turkes, 2014).

When we look at the effect of wind speed, this variable has a drying effect on fuel like temperature at the beginning of the forest fire, as well as affecting the behaviour and growth rate of a fired fire (Wagner, 1974). Because the wind can cause a fire to bounce at distances and cause the fire to grow.

Another variable, the amount of precipitation (with relative humidity), has an adverse effect on the occurrence of forest fires in comparison with the effects of temperature and wind speed. Precipitation over the region reduces the risk of fire due to increased soil moisture and fuel moisture content. On the other hand, when the amount and frequency of rainfall in the region is low, it has a negative impact on the risk of fire, because it reduces the moisture content (Wagner, 1987). Another variable used in the calculation of CFWI is the relative humidity that decreases with temperature (for saturated vapor pressure increase), but the relative humidity in the environment increases with precipitation. That is, relative humidity is usually high in rainy conditions, low in times of high temperatures. Accordingly, low relative humidity also means that the fuel's humidity is low. Therefore, when the relative humidity is high, the forest is in the low risk of fire, while in the opposite case it increases the risk (Wagner, 1974, Wagner, 1987, Bilgili, 2014, Sweet and Turkes 2014, Tatli 2015).

The CFWI values obtained from the study were rated in terms of fire-extinguishing risk and mapped using the ArcGIS 10.3 GIS program. The map obtained is shown in Figure 3. When looking at the risk map given in Figure 3, the risk-ratio decreases markedly from the coast to the inner periphery, which can be explained as one of the main causes of the rise in precipitation and relative humidity as the precipitation increases towards the interior. As it is seen in this map, the places with the least risk are the eastern, western and northern parts of the eastern southern parts of Biga, Çan, Yenice and Bayramic and Ayvacık districts. There is higher fire risk in this part of the coast and aaccording to the Northern part, said that changing the topography of the local meteorological conditions. Due to be a rugged nature of the topography and the Ida Mountains of assets with extension line to see a barrier in terms of overall air circulation, southerly hot dryer air type namely Lodos the impact of the break and with the weather, with a mass forced to rise passing the Ida Mountains be leaving precipitation along the high slopes. This increases the relative humidity of the eastern and southern regions of the study area, thus reducing the risk of fire-extinguishment as the wind reduces the drying effect.

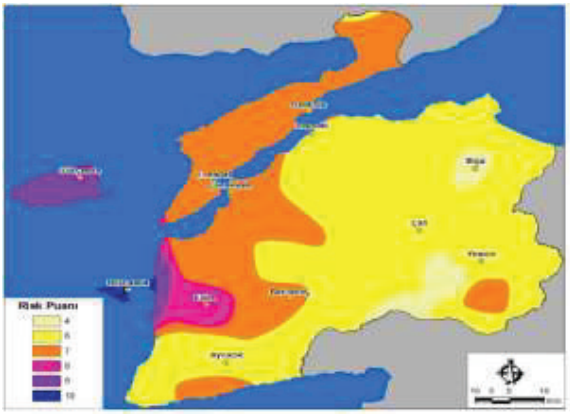


Figure 3. Forest fire air index classes as specified in a subjective manner

This study covers a part of a TUBITAK project that is still underway. In the related project, the risk map given in Figure 4 is obtained when many human and physical geographical factors take part in the account. This map is the most detailed risk map of forest-fire for this region, depending on the open literature. The reason for the awarding of this map is how much representation of the risk map obtained by the CFWI alone can be seen. Hence, the details were not given in this study.

When this last risk-map is examined, there is no low risk area on the entire land, which is in perfect agreement with the risk map obtained with CFWI. Moderately risky areas are observed in a few places. On the other hand, high and very-high risk areas cover the entire working area, except for non-forest areas. This risk seems to be risk-free because there is no forest in the settlement areas.

When the result map is taken into consideration, medium risk areas occupy very little locally between the Çanakkale-Lapseki-Bayramiç and Yenice-Çan-Biga districts. High risk areas are located over the high sections of the Ida Mountains, and the environment Biga, Çanakkale and Gallipoli Lapseki eastern covers the north-western part of the peninsula. Very high-risk areas located over the entire of Gökçeada, the southern parts of Bozcaada, along the Eceabat and Gelibolu shoreline, the entire forest area between Çanakkale-Ezine-Bayramic, Yenice and southern parts and Ayvacık surroundings. Extreme risk areas are locally located in the eastern parts of Gökçeada, northern parts of Bozcaada, between Bayramic and Ayvacık, around İntepe, in southern parts of Yenice, Northeast part of Bayramiç and northern parts of Saros Gulf (Figure 4).

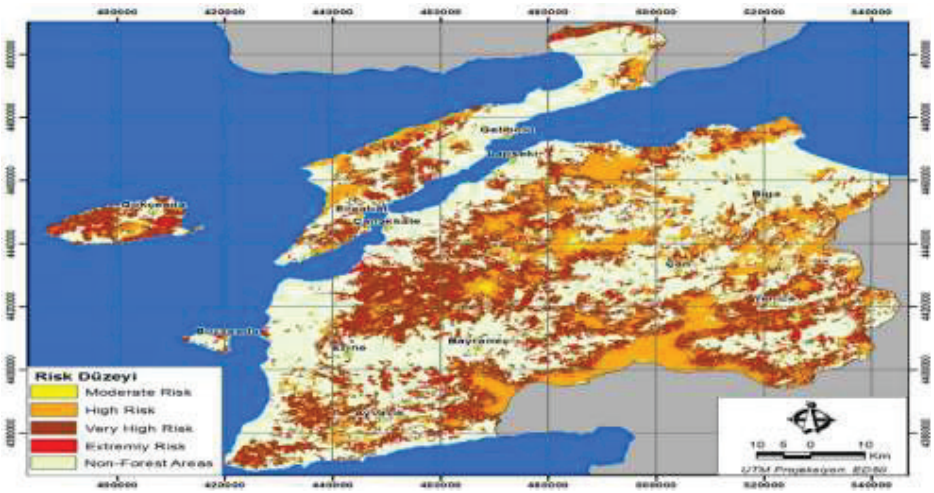


Figure 4. Forest fire-occurrence risk map resulting from all physical (including meteorology) and human geographical factors

CONCLUSIONS

The risk analysis of forest fire formation for Çanakkale was obtained by using the CFWI values given in Figure 3. This map can be seen as "high and very high risk" in terms of forest fire formation for Canakkale. As a result, it is thought that this study will provide great support in terms of forest fire fighting, minimizing fire-prevention and damages.

This study can be regarded as an important resource for the relevant institutions in terms of taking the necessary precautions in the field of work, especially for the very high risk areas covering large areas.It is recommended that these risky areas should be cleaned from

combustible fuels primarily in forest settlements, near agricultural areas and roads close to forest areas, and that the fire in these areas should be informed through direct training and media.

In addition, the related fire-information networking systems which using risk maps of forest fires. Accordingly, the related fire-intervention equipment must be put in the critical places selected from the risk maps in order to prevent the growth of fires. Prior to the occurrence of a possible fire, necessary safety measures can be taken, such as reducing the amount of fuel under the forest. If these and similar fire monitoring and intervention studies are given primarily high-risk and very high-risk field weight, both the number of fires and the magnitude of fires can be reduced. One of the noteworthy shortcomings of the study area is the lack of numbers of meteorological stations and the fact that they are not located in the prerequisite places for fire monitoring and follow-up to take more realistic and reliable data. The permanent meteorological stations can also be placed at suitable places where the necessary measures can be taken in the forest areas and informing the public as well as providing the necessary data. This study has shown that CFWI approach can be used in forest fire risk analysis to give good results. The application of this method in other areas will also benefit from the investigation of its validity. First of all, within the scope of combating forest fires, it is the high public benefit of the country that the necessary financial support of the relevant public institutions is provided for this and similar works.

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