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Determination of Meteorological Forest Fire Risks in Mediterranean Climate of Turkey

Gülşen KUM*, Mehmet Emin SÖNMEZ
Gaziantep Üniversitesi, Fen Edebiyat Fakültesi, Coğrafya Bölümü, Gaziantep

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ABSTRACT: Located in the Mediterranean climate zone, Turkey is one of the countries where hundreds of forest fires occur every year. Especially the West Taurus is one of the most affected areas. Some fires occur naturally due to the climatic facts. The fires occurring due to negligence or intent also expand their domain largely in the control of climate elements. Therefore, it is of great importance to determine the natural fire risk of the region depending on the climatic factors. In this study, to determine the natural fire risk, the Keetch-Byram Drought Index was used and The Inverse Distance Weighting method was applied to the index results by using the Arc GIS software. Also in our study, the results obtained with the Keetch-Byram Drought Index were compared on a monthly level with the number of fires occurred in 2011 in the same area. Both the accuracy of the Keetch-Byram Drought Index and also distribution of natural fire risk areas in the Western Taurus were determined. According to the findings, during the period from July to November, when drought increases, the values increased based on meteorological conditions. It can be concluded that the risk is particularly high in late summer months (August and September).
Key Words: Keetch-Byram Drought Index, The Western Taurus, Forest Fire, Fire Risk

Türkiye Akdeniz İkliminde Meteorolojik Orman Yangını Riskinin Belirlenmesi

ÖZET: Akdeniz iklim kuşağı içinde yer alan Türkiye, her yıl yüzlerce orman yangının meydana geldiği ülkelerden biridir. Özellikle Batı Toroslar yangınlardan en çok etkilenen alanların başındadır. Bu yangınların bir kısmı iklimin etkisiyle doğal yollardan meydana gelmektedir. İhmal ya da kasıtla meydana gelen yangınlar ise büyük ölçüde iklim elamanlarının kontrolünde etki alanlarını genişletmektedir. Dolayısıyla bölgenin iklim faktörüne bağlı doğal yangın risk haritasını belirlemek büyük önem taşımaktadır. Çalışmada doğal yangın riskini belirlemek için Akdeniz iklim kuşağında yangın riskini belirlemede güvenirliliği kanıtlanmış olan Keetch-Byram Kuraklık İndeksi tercih edilmiştir. Bu amaçla çalışma sahası sınırları içinde bulunan 24 meteoroloji istasyonunun günlük verileri Keetch-Byram Kuraklık İndeksi'nde değerlendirilmiştir. Elde edilen sonuçlara Arc GIS programında IDW yöntemi uygulanmış ve çalışma sahasının Keetch-Byram Kuraklık İndeksi'ne göre doğal yangın risk haritası oluşturulmuştur. Ayrıca çalışmada Keetch-Byram Kuraklık İndeksi yöntemiyle elde edilen sonuçlar ile çalışma sahasında 2011 yılında meydana gelmiş olan yangın sayıları aylık düzeyde karşılaştırılmıştır. Böylece hem Keetch-Byram Kuraklık indeksinin doğruluğu test edilmiş hem de Batı Toroslar'daki doğal yangın risk alanlarının dağılışı belirlenmiştir. Bulgulara göre, Temmuz'dan Kasım'a kadar olan devrede, kuraklık arttığında meteorolojik koşullara bağlı olarak değerler de artmaktadır. Meteorolojik kökenli riskin özellikle yaz sonu (Ağustos ve Eylül) yükseldiği söylenebilir.
Anahtar Kelimeler: Keetch-Byram Kuraklık İndeksi, Batı Toroslar, Orman Yangınları, Yangın Riski

INTRODUCTION

Forest fires take place in different climate zones across the globe from the north to the south due to climate, land use, negligence and intention (Vilen and Fernandes, 2011, Ganteaume, et al., 2013). Forest fires can also naturally occur frequently especially in the Mediterranean climate zone where summer is hot and dry. High temperature, wind and low relative humidity are often associated with drought (Tanoğlu, 1943) and forest fire. Yet, it is known that climatic elements such as temperature and drought are extremely influential on the burning period and spread of the forest fires that occur due to anthropogenic reasons. By and large, meteorological drought arises as an outcome of natural variability of the climate itself. It occurs as a result of the relatively long-lasting effect of the high pressure systems in a specific region caused by the changes in patterns of large-scale pressure and wind circulation and atmospheric oscillation (Kutiel et al., 2001; Türkeş and Erlat, 2003). Indeed, it has been demonstrated in several studies that increases of meteorological drought due to climate oscillations affect the frequency of fires in a positive direction. For example, during the years 1997 and 1998, strong El Nino conditions accompanied the extreme drought conditions and forest fires in many areas covering Indonesia, East Russia, Central America, Brazil and Florida (Nicholls, et al. 1996). Similarly, among the forest fires that took place throughout 2013 in 29 countries including Europe, Middle East and North Africa, Portugal was on top of the list with the highest number of fires where summer drought prevails and lasts long. It is followed by other countries such as Spain, Italy, Algeria, Turkey and Greece also are among the countries adversely affected by forest fires (European Commission, 2014). Therefore, although forest fires occur due to different reasons, the area affected by the fire, duration and course of the fire is largely controlled by climatic elements. It is a fact that

* Corresponding author: Kum, G., gulsenkum@gantep.edu.tr

there is a strong link between drought and forest fires in the summer in the countries in the Mediterranean climate zone (Camia and Amatulli, 2009). In these countries, prolonged drought and strong winds (Ganteaume, et al., 2013) coupled with high temperatures and low rainfall values (Petritsch and Hasenauer, 2014) emerge as the most important causes of natural forest fires. In many studies it is reported that the fires that naturally occur in the Mediterranean climates increase since the end of May reaching the maximum level in August and September (Ayanz, et al., 2013; Ganteaume, et al., 2013; European Commission, 2014).

In the Western Taurus (Turkey), which is subject of our study, the number of fires as well as the amount of land destroyed as a result of the fires go up to the maximum level during summer (OGM, 2015).

With the aim of determining the risk areas of natural forest fires, remote sensing and Geographic Information Systems based on different parameters (Pradhan et al., 2007; Pourghasemi et al., 2014; Pourtaghi et al., 2015) and different methods depending on the meteorological data can be used (Niu and Zhai, 2012). However, the Keetch-Byram Drought Index (Keetch and Byram, 1968) based on meteorological data such as daily maximum temperature, the amount of daily precipitation and mean annual precipitation is one of the most commonly used methods for this purpose (Janis et al., 2002; Petritsch and Hasenauer, 2014).

The objective of this study is to investigate the relationship between fire risk and meteorological conditions in the Western Taurus. Besides, the present study aims to examine whether KBDI values can adequately reflect fire risk for the Turkey under the Mediterranean climate conditions.

MATERIAL and METHODS

Keetch-Byram Drought Index (KBDI) was used in order to determine high-risk area and high-risk period based on climate conditions. To map data which is calculated on the basis of the index, the Inverse Distance Weighting (IDW) toolbar was used as it is based on the average distance weight among GIS (Janis et al., 2002; Cao et al., 2010). Furthermore, the forest areas covered in the study area were identified using the remote sensing method. Consequently, it was found out which parts of the existing forest areas are under risk, to what extent and how serious such risks are.

KBDI Calculation

One of the best known properties of air is that it is a critical element of fire potential assessment (Feidas, 2002). In the present study, the Keetch-Byram Drought Index (Keetch and Byram, 1968) was used as it is one of the world's most common drought indices to determinate the fire risk. KBDI is basically focused on changes occurring in the soil moisture as a result of evapotranspiration in the ecosystem. Moisture deficiency in the soil is remedied by precipitation variables only. The density of vegetation is determined by average available moisture. The places with high amount of total annual precipitation also hold dense vegetation and thus high transpiration (Janis et al., 2002). Developed by John Keetch and George Byram in 1968 for the United States Department of Agriculture's Forest Service, the index consists of a formula describing the soil moisture deficiency at conceptual level based on cumulative calculation system. KBDI is a calculation quite responsive to rainfall change on a daily basis. Such rapid response is critical for forest fires which will reduce the danger depending on marked rainfall (Goodrick, 2003). Application of the KBDI does not require a lot of parameters. Only maximum temperature and precipitation data are used. Still, the index has a very wide use. The use of the KBDI in a wide range of geographical areas- for example in Northern Eurasia (Groisman, 2007), Hawaii (Dolling et al., 2005), Australia (Finkele et al., 2006; Boer et al., 2009; Caccamo et al., 2012), Russia (Malevsky-Malevich et al., 2008), the Mediterranean basin (Ganatsas et al., 2011; Türkeş and Altan, 2014), Southeast Asia (Buchholz and Weidemann, 2000; Murdiyarso et al., 2002; Ainuddin and Ampun, 2008) and the USA (Haim Jr., 2002) indicates that the index is considered as an acceptable application. The index aims to estimate drought in the litter and duff layers. In the case of drought in depth, it is assumed that additional fuel is available as a prerequisite for flaming of the fire (Burgan, 1988). In the KBDI; soil moisture loss is determined by evapotranspiration relationships and it is exponential. Field capacity of soil is calculated as 8 inches (20.32 cm).

The KBDI is an index applicable for each selected area regardless of the amount of annual rainfall. However, 5 tables are utilized with different ranges of precipitation related to drought factor in order to facilitate calculations. The climatic inputs for drought index calculation are daily maximum temperature/dry bulb temperature values (°C), the last 24 hours of total rainfall (mm) and mean annual precipitation values at selected weather station for deciding which table to use. For each temperature selected from the table, the new drought factor calculated receives a different value depending on the drought factor for the previous day. It proves the cumulative aspect of the formula. Thus, the index does not start from the value of zero (0) automatically. In experimental index calculation, index calculation can be initiated on the basis of meteorological data. The formula is initialized with different criteria in different indices. According to the KBDI –assuming the soil saturation near full level- it is suggested to start up when rainfall close to field capacity is 150 mm. The Nesterov Index (NI) suggests starting up 3 days after snow melting; while Canadian Forest Fire Weather Index (FWI) suggests that the formula can be started in a period when mean daily temperature is 6 °C for three consecutive days – assuming that plant growth starts then though it does not affect the formula (Ganatsas et al., 2010). As also apparent from the description, the only drawback in the KBDI implementation is the fact that not all climate zones would not be appropriate for starting the formula The drought factor could have been measured as zero (0) much earlier than the day of the application period. To start up the formula, it is necessary to go back from the application period-back to the week with 150-200 mm rainfall. The following day, the index is started with zero (0) assuming that the soil saturation is at maximum level. Soil saturation varies by geographical region. However, it can reach that level at the end of a long wet period (Janis et al., 2002).

In this formula, drought increases only at times wherein precipitation is less than 5.1 mm or none and temperature is above 6.78 ºC. When it rains, the amount above the specified value (5.1 mm) is subtracted (or decreased) from the index.

Depending on the temperature (T) and precipitation (P) conditions, the following equations are used:

Condition 1: *If* $P=0$ *mm and* $Tmax \leq 6.78$ ºC $KBDI=KBDI_{t-1}$
Condition 2: *If* $P=0$ *mm and* $Tmax > 6.78$ ºC $KBDI=KBDI_{t-1}+DQ$ (1)
Condition 3: *If* $P>0$ *mm and* $\sum P \leq 5.1$ *mm* $KBDI=KBDI_{t-1}+DQ$
Condition 4: *If* $P>0$ *mm and* $\sum P > 5.1$*mm* $KBDI=KBDI_t+DQ$
$KBDI_t= KBDI_{t-1}-39.37 \sum P$

In condition 1, rainfall is zero (0) and temperature does not exceed 6.78 °C, the KBDI value does not change. In condition 2, KBDI increases in proportion to the daily maximum temperature. In condition 3, there is rainfall still total precipitation in succession is less than 5.1 mm, the KBDI increases only proportional to temperature. In condition 4, there is rainfall and total precipitation in succession is above 5.1. In this case, KBDI increases with temperature, but the increase in rainfall moderates such increase (Janis et al., 2002) When precipitation is more than 5.1 mm, it is subtracted only for the first rainy day from total rainfall to obtain the net rainfall amount.

The units used in the original formula are inches and ºF for rainfall and temperature, respectively. Following equation is used accordingly:

For equation inches (Keetch and Byram, 1968; Alexander, 1990);

$$dQ = \frac{[800 - Q][0.968\exp(0.0486T) - 8.30]dT}{1 + 10.88\exp(-0.0441R)} * 10^{-3} \quad (2)$$

Since we use mm and ºC for rainfall and temperature, respectively, will this study, the equation will be used after being transformed into the following form. Then, it will be converted to original values in the KBDI.

For equation mm (*Crane*, 1982);

$$dQ = \frac{[203.2 - Q][0.968\exp(0.0875T + 1.5552) - 8.30]dT}{1 + 10.88\exp(-0.001736R)} * 10^{-3} \quad (3)$$

Here, **dQ** stands for drought factor (inch or mm), and **Q** for moisture deficiency (KBDI value for the previous day or value as reduced by the daily net precipitation values). (i.e., the amount in excess of 0.20 inches or 5.1 mm); **T** is expressed as daily maximum temperature (°F or °C); **R** as mean annual rainfall (inches or mm); and **dT** is expressed as time increment (1 day) (Alexander, 1990).

The obtained KBDI values were categorized to determine different levels of fire risk in order to facilitate the explanation and clarify discussion on drought. As progress is made from zero (0) towards 800, moisture deficiency in the soil increases. In other words, 0 refers to maximum soil saturation with minimal fire potential. On the other end, 800 indicate the highest level of soil moisture deficiency with fire potential at maximum level (Table 1).

Table 1. KBDI fire risk levels

KBDI	Risk Levels
< 99	Very Low
100-199	Low
200-299	Moderate
300-399	High
400-599	Very High
600 +	Extreme

In relation with the fire risk dependent on drought, evaluation was made on year 2011 and 24 stations were used (Figure 1). 2011 was preferred due to the fact that missing station data were minimum and that year was the closest period to present. Regarding the stations in this study, daily maximum temperatures as well as daily and yearly total rainfall data for 2011 were obtained from Turkish State Meteorological Service via Meteorological Data *Archive* and Management System (TUMASTSMS). By nature of the formula, the KBDI values were calculated on a daily basis depending on the drought factor determined by the amount of annual rainfall. Then, in order to determine the seasonal fire potential, arithmetic mean of the daily values was calculated to convert to average monthly values. Besides this, the number of forest fires in selected stations obtained from relevant Forest Regional Directorates' archives was overlaid with the KBDI values. In this way, the applicability of the index to unravel the fire potential was tested by various calculations.

IDW Method

For the mapping works, the methods of Geographic Information Systems and Remote Sensing were used. It is particularly important to take into account and map the KBDI values in areas without a sample point. Various techniques were used to do this. The most common is thought as the IDW method because in this method approximate values are given automatically to unsampled areas according to the sampled areas (Janis et al., 2002). The new values given to the unsampled points cannot be below the lowest or above the highest minimum value (Cao et al., 2010). Despite several shortcomings of the IDW method, it is widely used as it is flexible, objective and capable of estimating to eliminate uncertainty (Tomczak, 1998). Therefore, for mapping of the KBDI data, the IDW method was used in this study.

To determine forest areas, the remote sensing method was utilized in the study. The Landsat OLI/TIRS satellite images for July 2015 were downloaded and subjected to uncontrolled classification using the remote sensing method. Of the 50 uncontrolled classes, the forest areas were determined and mapped as in Figure 1.

The risk map and forest lands determined by the KBDI were overlaid in the Geographic Information Systems (GIS). For this, the overlay bar within the GIS was used to reveal the relationship between forest lands and risk groups.

Study Area

The study area roughly covers the Antalya sub-region situated within Turkey's Mediterranean Region. The study area covers approximately 6.3 million hectares, about 32% of which (2.040.000 million hectares) is covered by forests and shrubs. 24 weather stations in this area were used for the calculation (Figure 1).

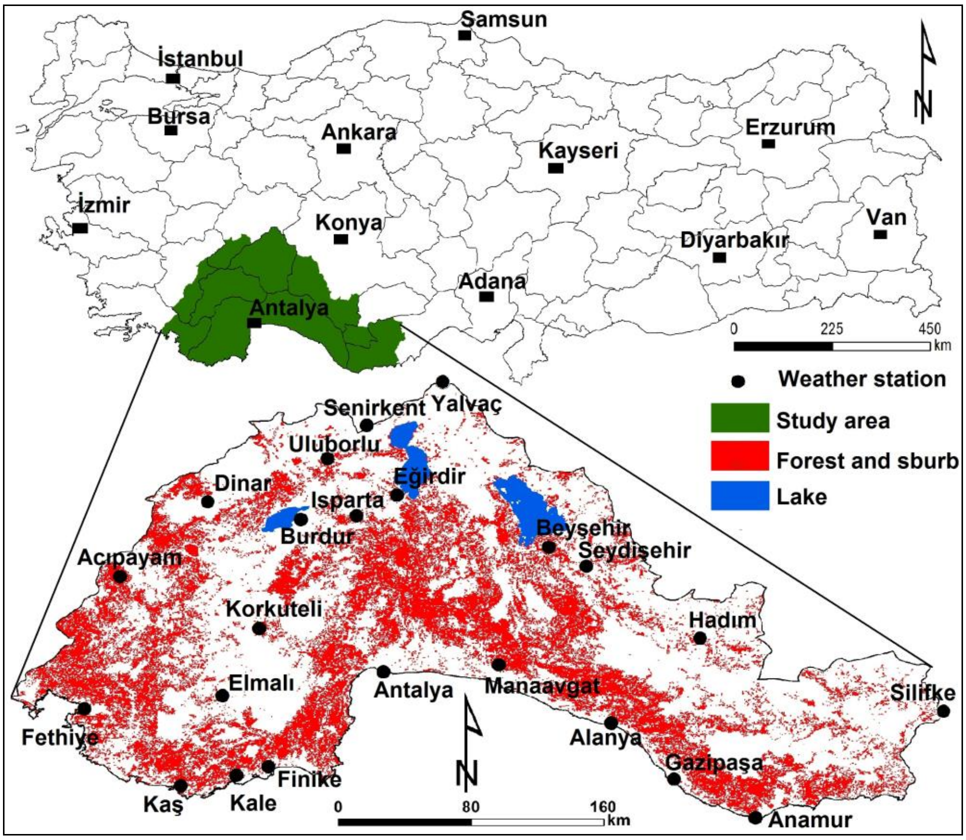

Figure 1. Monthly mean KBDI values for all stations in the study area from January to December

Throughout the study area, elevation roughly increases from south to north (in Taurus) and falls again in the Lakes Region. Elevations in the study area ranged from 0 to 3086 meters (Figure 2). Whereas the real Mediterranean climate is seen in the coastal areas overlooking the Mediterranean, it is replaced by continental climate on the Taurus Mountains, which have a higher elevation, and in the inland Lakes Region.

Vegetation types within this study area consist of forest and shrubs. Across the Western and Central

Taurus, red pines (*Pinus brutia*) are dominant below 1000-1200 meters, while rigid and leafy maquis grow in destroyed areas. The areas with destroyed maquis are mostly covered by garrigue piles. Conifer forests spread after 1000-1200 meters, starting with Anatolian black pine (*Pinus nigra*) which can withstand lower temperatures, followed by cedar (*Cedrus libani*) and cilician fir (*Abies cilicica*) (Atalay, 1989; Avcı, 2005).

Majority of the area is under the influence of the Mediterranean climate. In this climate, summers are dry due to the subtropical high pressure, while winters are wet due to the western winds-cyclone belt. The precipitation regime is determined by frontal activities and topography. In coastal parts, frontal activities are effective moving from southwest to northeast in winter. Such activities cause orographic rainfall on the slopes of the Taurus resulting in an increase of rainfall especially in coastal stations in the upright position to the wind. The wind regime in the field is mainly determined by factors of air circulation, the topography and land-sea activities. In summer, interruption of the circulation and stability conditions sometimes cause winds to dominate the field depending on the maritime activity (Erinç, 1996).

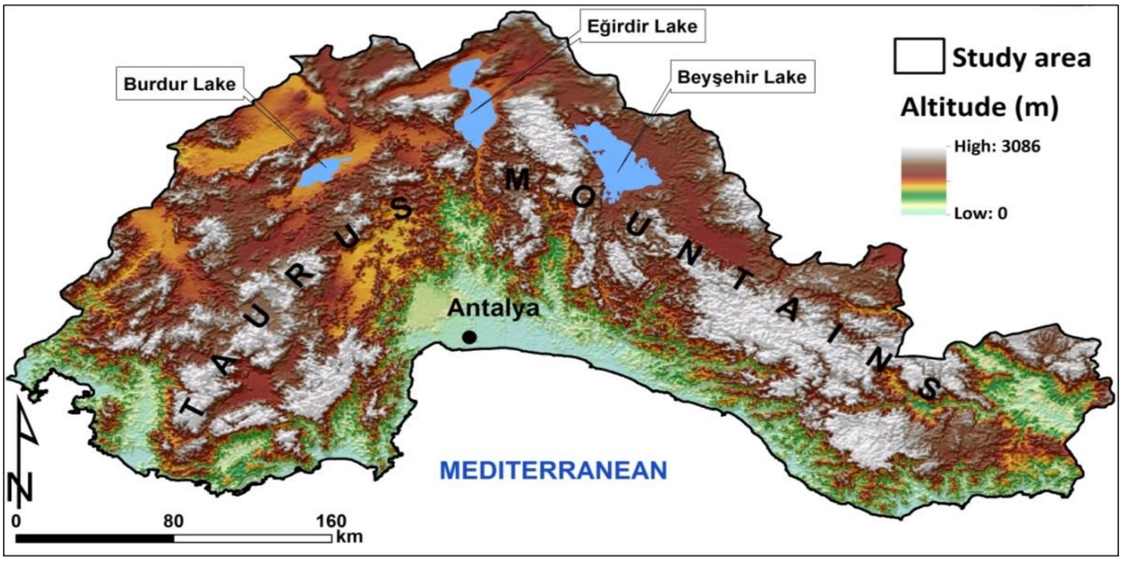

Figure 2. Digital elevation model of the study area

RESULTS

The distribution of KBDI values by months is given in Table 2. It is seen that the KBDI values are lowest during late winter and spring, while they reach the maximum level in summer and autumn. According to findings there is no station with meteorological high fire risk value except for Antalya (348) and Burdur (268) during the winter. During spring, the overall index values also remain below 250. In early summer, values tend to increase especially in coastal stations; there is not a significant difference in the inland stations. There is increased risk of fire for all stations in July and August, the increase being greater in coastal stations. Though peak KBDI values especially in September indicates increased duration of dry periods, such an effect may be related to climatic oscillations and active periodic Monsoon (Basra low pressure is the extension of the Monsoon low in Turkey). The increase in risk potential in September is related to the precipitation parameters rather than temperature because precipitation is the only factor that could decrease the KBDI values in the formula. The lack of increase in rainfall has led to postponement until next month of the effect that will reduce risk values. In September, the values range from 450 (Hadım) to 753 (Manavgat). Thus, September seems to be the month in the ‘’very high’’ and ‘’extreme’’ fire potential category in the index. In spatial distribution of KBDI data, relatively higher risk value is observed in coastal stations corresponding to the influence area of the typical Mediterranean climate.

Table 2. KBDI fire risk levels (from 0-800 inches)

Station	Jan.	Feb.	Marc	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Antalya	348	242	33	21	100	314	577	723	636	586	637	529
Manavgat	21	9	57	71	153	390	620	743	753	493	417	251
Kale	23	23	47	56	168	364	567	703	711	406	351	223
Alanya	23	20	34	32	94	268	541	702	641	161	188	98
Fethiye	21	26	33	63	148	330	576	708	628	278	259	124
Anamur	24	8	32	62	131	286	524	669	710	539	571	217
Finike	12	17	25	41	185	408	611	734	725	471	428	222
Gazipaşa	24	16	15	47	65	153	419	596	662	452	327	113
Kaş	23	11	28	56	82	178	417	589	675	392	294	136
Köyceğiz	23	14	68	134	259	478	687	762	751	354	320	180
Mersin	35	8	17	79	112	251	379	531	617	560	486	291
Silifke	27	11	26	75	75	91	318	522	639	620	561	314
Burdur	268	181	62	9	35	40	212	421	538	525	508	502
Isparta	113	30	1	5	51	132	278	458	562	472	433	414
Eğirdir	0	0	3	18	45	172	375	558	651	383	248	125
Beyşehir	0	0	0	4	46	145	276	423	529	374	283	188
Yalvaç	31	0	0	2	13	89	255	472	574	467	373	346
Elmalı	0	0	27	18	54	75	231	417	521	359	268	195
Uluborlu	52	0	3	11	22	82	266	455	570	460	398	338
Hadım	0	0	0	0	8	40	158	345	450	327	224	127
Senirkent	82	0	4	20	41	45	231	468	591	476	406	344
Seydişehir	0	0	4	6	13	90	296	514	634	354	217	73
Korkuteli	151	24	2	3	9	51	211	396	510	471	449	424
Acıpayam	89	0	15	56	42	142	336	532	642	535	476	435

Figure 3 displays the spatial distribution of the KBDI data between June and October obtained by IDW method in the study area. In this way, the difference of fire risk between the inner part and the coastal areas under the influence of the real Mediterranean climate can be seen more clearly (Figure 3). Individual areas being exceptional, it is seen that fire risk is greater in the inland areas in the north of the Taurus and in karstic depression areas due to differences in the course of temperature and precipitation parameters. Besides, channelling of the wind through the north-south valley gutters affects the direction and speed of the wind, which both expands the spread area of the fire and makes it difficult to control it. On contrary, especially in coastal areas under the influence of the real Mediterranean climate, fire potential rapidly increases in parallel with the dry period. As evidence, the KBDI values in the coastal areas where the real Mediterranean climate is seen exceed 600 from July on. However, in the Lakes Region (continental-Mediterranean/transitional-Mediterranean), the value of 600 is approached towards the end of August and it is not reached until September since it is inland and drought is felt more slowly. In October, the KBDI values fall sharply with the onset of autumn rains in overall region especially along the coastal area, hence and the fire risk declines (Figure 3). This suggests that the natural fire risk in areas dominated by the real Mediterranean climate is much higher compared to other climate regions.

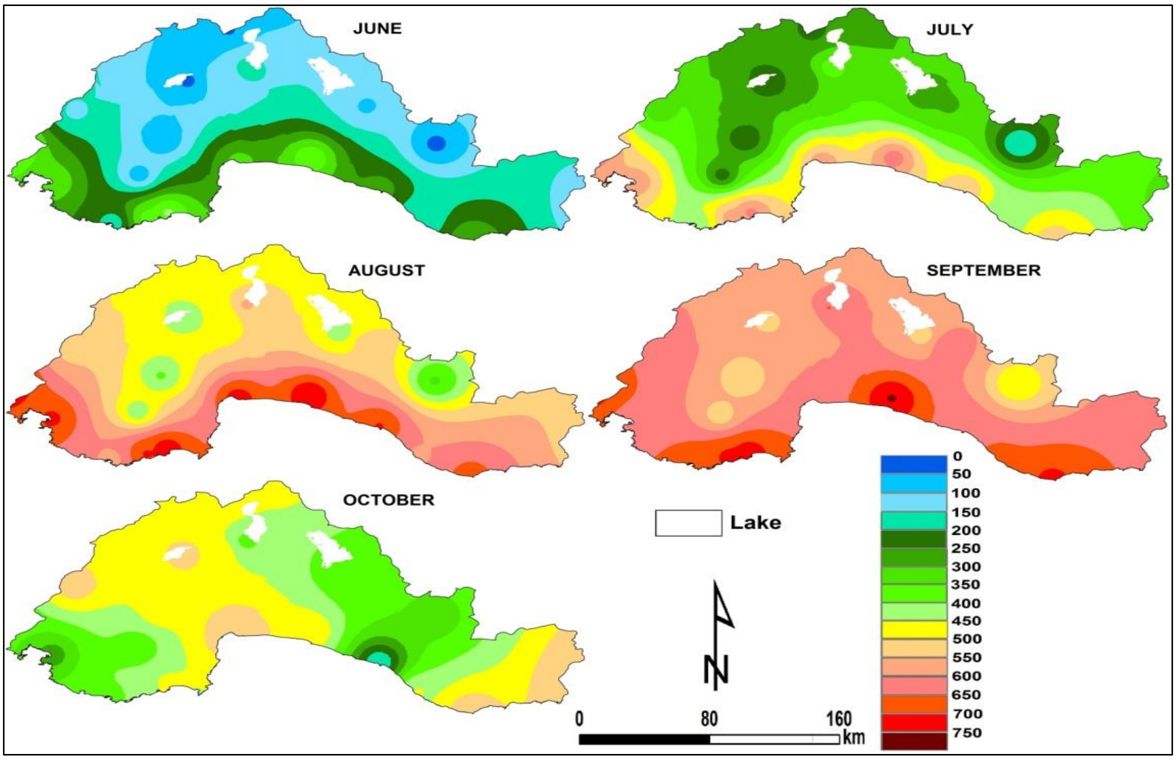

Figure 3. Relationship between KBDI risk levels and forest areas from June to October

In the study, the weather station data obtained with the KBDI were processed by using the IDW method. Consequently, natural fire risk values of the field study were determined. The resulting natural fire risk values were overlaid with forest areas of the field studies using the Overlay toolbar. As a result, it was seen that nearly 55 % (1.119.300 hectares) of the forest in our study area is under low or very low risk of natural fire throughout June. In this month, about 715 thousand hectares are exposed to middle level of natural fire risk, 210 thousand hectares are faced with high risk, and only 2.300 hectares are under very high risk of forest fire (Table 3).

In July, natural fire risk level shows an increasing tendency. In reality, only 8.700 hectares and around 290 thousand hectares remain under low and moderate level of risk, respectively, in July. In contrast, around 730 thousand hectares of forest areas are subject to high risk, more than 1 million hectares is faced with very high risk, and lastly 14.100 hectares are extreme risk (Table 3). Across the forest areas within study field, natural fire risk in August further increases compared to July. In this month, there are no forest areas under very low, low to moderate level of fire risk. While only 13.900 hectares seem to be under high fire risk, the rest of all forest and bush areas pose a very high and extreme level of fire risk. Across this study area, natural fire risk in the forest areas reaches maximum level in September. It is already noted that all forests and shrublands in the work area are faced with very high and extreme fire risk. In October, fire risk of the forest areas in this area is reduced compared to the previous month. During this period, 19.700 hectares of forest and bush areas are at low risk, approximately 90.000 hectares at medium risk and another 550 thousand hectares are under high risk of fire. However, the rest of approximately 1.5 million hectares of forest and shrublands are faced with very high fire risk (Table 3).

In order to reveal the relationship between KBDI values and forest fires and the amount of burnt area, average monthly KBDI values for selected stations were overlaid with the number of fires and the amount of burnt area (Figure 4).

In the first six months of the year, during which too low and low fire risk is seen, 58 forest fires were recorded. Despite the low level of fire risk in June (192), a total of 34 fires occurred then. It seems that such fires might have occurred due to reasons such as malice and so on. Yet, relatively small amount of burnt areas (11.4 ha) seem to support the possibility that meteorological conditions do not allow the spread of fire. In July, August, September, October, and in November, when KBDI values fall into high value, very high and extreme risk category, the total forest area of 280 hectares are lost in 212 fires. 87.9% of the fires that occurred in 2011 corresponding to 88.8% of the burnt area occurred during months when KBDI values are 300+ referring to high, very high and extreme fire risk levels. In the stations, average KBDI values from September are seen as 600^{+}, which corresponds to extreme fire risk. During this month, a total of 61.4 hectares of land were destroyed in 65 forest fires. As calculations are applied to stations only the main Mediterranean climate prevails, risk values are likely to be higher.

Table 3. Relationship between KBDI risk levels and forest areas from June to October (The table was produced using the overlay technique)

	June	**July**	**August**	**Septem.**	**Octob.**
	Area (ha.) ((Has	*Area (ha.)*	*Area (ha.)*	*Area (ha.)*	*Area (ha.)*
0-50	7200				
50-100	153300				
100-150	464500				
150-200	494300	8700			19700
200-250	433700	46400			25300
250-300	283100	241300			63200
300-350	156200	449600	1600		138600
350-400	54600	278500	12300		419300
400-450	2300	358200	68700		447500
450-500		343800	334900	14200	775800
500-550		206500	489800	61600	159800
550-600		102100	344700	517300	
600-650		14100	472200	983900	
650-700			269800	393300	
700-750			55200	76100	
750+				2800	

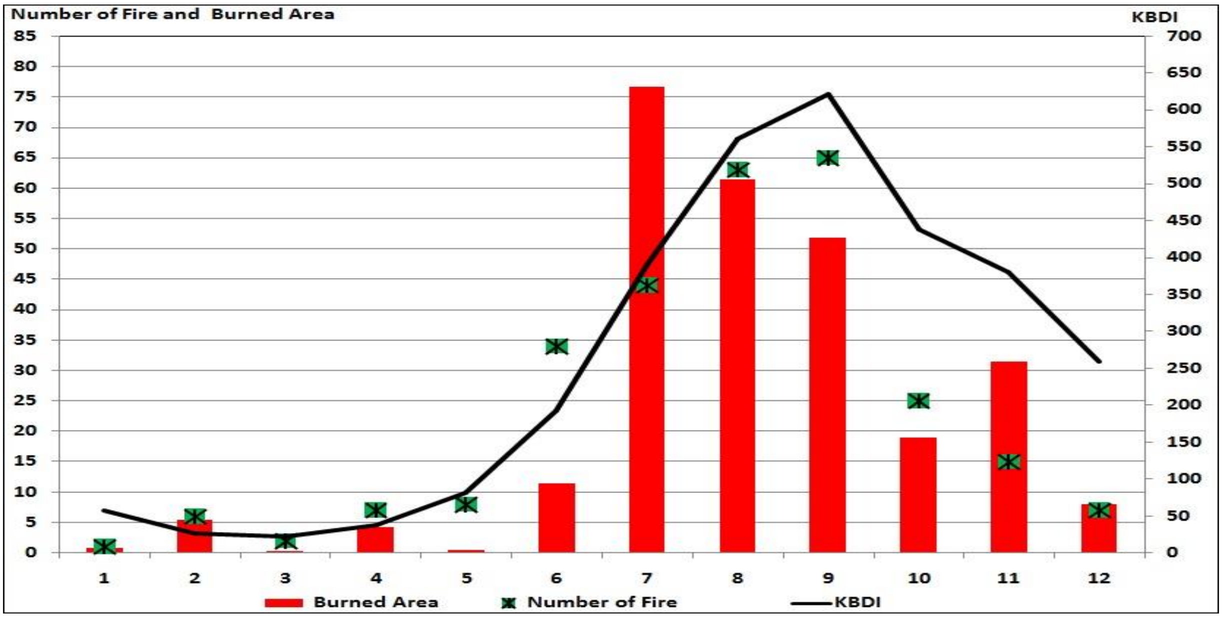

Figure 4: Associating categories of fire risk with number of fires and the amount of the burned area

In figure 5, fire risk categories are illustrated in association with the number of fires. During periods of remarkable drought, climatic conditions seem to be available for 14% of the total fires falling into the high risk group with 300-399 KBDI values. This can be said for 39 % of those in the very high risk category with KBDI values of 400-599. Lastly, it seems to be the case for 35% of the fires occurring under extreme risk (600+).

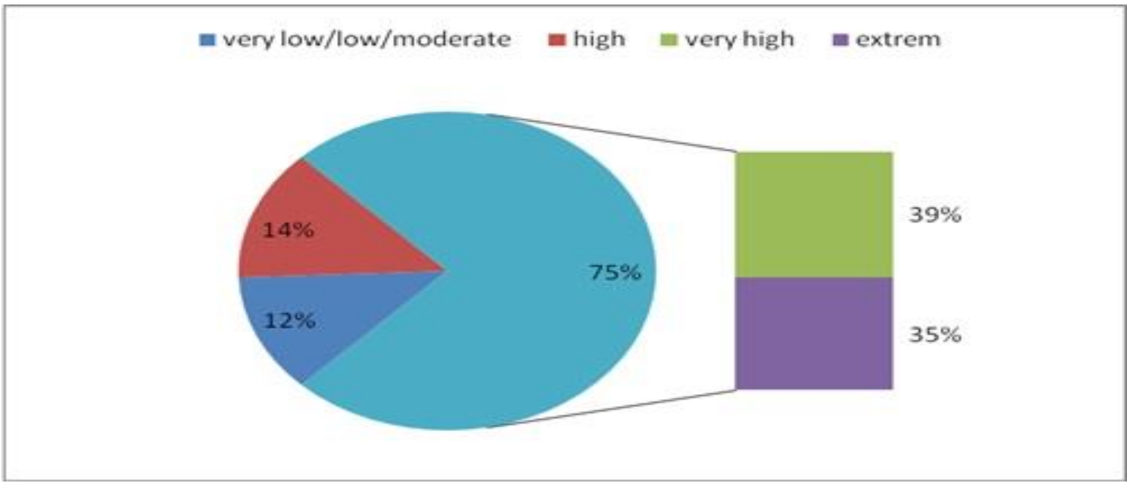

Figure 5. Proportional distribution of KBDI fire risk groups by number of fires (very low-low-moderate: 0-299 KBDI; high: 300-399 KBDI; very high: 400-599, and extreme: 600^{+} KBDI.)

CONCLUSION

This study was carried out to investigate the relationship between fire risk and drought in the study area, and KBDI was used for this purpose. It was found out that the index reacted rapidly to meteorological data revealing the relationship between summer drought and forest fires. According to the findings, the western part of the southern coast of Turkey under the influence of the Mediterranean climatic conditions faces a high fire potential due to both characteristic climatic conditions. In fact, the index yielded higher values during 2011 particularly in summer and subsequently September as drought is severe then. According to the calculations of index based on 24 weather stations, it can be said that, in the Mediterranean Climate zone, fires frequently occur in September not only in Mediterranean climate stations but also in Continental-Mediterranean climate stations. That means that, forest fire management is extremely important in late summer. During the period from July to November, when drought increases, it is found out that the values increased due to the PET impact (potential evapotranspiration) based on unfavourable meteorological conditions. The risk is particularly high across the stations in August and September. In fact, in hot and dry summer in 2011; the surface soil, surface air and high atmospheric conditions (hot, dry stable, low humidity and high saturation deficiency, etc.) have been transferred to September, and this month has started under these conditions. Within this period when tropical Monsoon circulation continued, 2 September 2011 was recorded in as a day when 33 fires occurred in one day throughout Turkey (Türkeş and Altan, 2014). This reveals in a very clear way the relationship between climate and fire risk.

Perhaps the most important consequence of climate change for Mediterranean countries can be the shift of the high pressure belt at 30 degrees latitude up to the north, in other words, the expansion of the area of Hadley cell (Lu et al., 2007). For the Mediterranean countries, this can lead to enhanced impact of drier conditions ultimately triggering the risk of desertification. Thus, it implies that natural fire risk can increase gradually in the future along the Mediterranean climate zone in which the study area is also included.

Another important factor triggering the directing fires is constituted by maquis and forest flora, which is the typical xeric vegetation of the Mediterranean ecosystems. High temperatures and precipitation deficiency make fuels more suitable to ignite. As a result, fire risk increases along with high levels of drought and temperature in this region. Forest fire danger usually rises during the dry season due to rainfall deficiency. As precipitation decreases, soil evapotranspiration consumes moisture for compensation. Then, forest vegetation turns into lighter (fuel) and burning material (Taufika et al., 2015). Previous studies show that soil moisture deficiency affects the moisture content of dead fuels (necromass and surface litter, e.g.) (Pook and Gill, 1993; Pellizzaro, et, al., 2007). Also in the study, it was found out that the number of fires increases during months when KBDI values across the Western Taurus go up. By individual stations, it was also seen that the number of fires were particularly higher along the coastal areas with increased KBDI values. This in turn reveals that the KBDI is extremely reliable in determining the risk of fire in the Mediterranean climatic zones. It can be truly argued that it becomes difficult to provide description of drought in a specific area due to the facts that drought is not a parameter that can be measured directly, rather it can be defined by using different scales and indices with different approaches and opinions, drought conditions in the past had increased at least as much as today in cases such as El Niño, and challenges in measuring the soil moisture (Kurnaz, 2014). In particular, the trouble in measuring soil moisture measurements at each station suggests fires due to drought, thus restricting the ability to take precautions. Because the KBDI used in the study allows measuring of soil moisture by indirect still accessible parameters, it can be considered a successful formula to determine the potential for climatic fire risk.

Despite the influence of human-induced climate change (Gillett et al., 2004), fire extent is still linked to inter-annual climate variations. Climate variability influences wildfire activity on a regional scale (Trouet, 2006). As a result, drought and fire are natural components of the ecosystem in sites under the influence of the main Mediterranean climate (Trabaud, 1994). However, the increase of anthropogenic factors including tourism, livestock grazing, etc. have recently pushed forest fires out of the ecosystem management resulting in their ceasing to be a natural component in these areas. Prolonged duration of drought in parallel with climate change also causes increases in duration and severity of risky periods. Because fire forces edaphic, biotic and climatic factors to change, it is an issue that requires better deciphering from cause to solution and developing strategies accordingly.

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