The Analysis of the Forest Fires in Turkey with Statistical Quality Control Method

Mertol Ertuğrul, Tuğrul Varol, Halil Barış Özel

Bartin University Faculty of Forestry

**Abstract:** Fire is one of the most serious hazards for forests on earth. Despite each kind of technological development and equipment, fire activity has an increasing trend because of especially climate change and socio-economic reasons. Although fire extinguishing organizations, today, try to suppress this increasing risk with a maximum effort, the big fires in some places cause the enormous areas to get burned. The fires as big as natural disasters cannot be extinguished most of the time in spite of any efforts or methods when the extreme fire weather conditions come together with inflammable matters and ignition sources.

In this study, the number and area of forest fires in Turkey were investigated through statistical quality control method. Despite the decreasing trend of forest fires in terms of area size, the possibility of large fires always exists in the whole Mediterranean Region due to the socio-economic conditions such as increasing human population, migration and any changes that could affect fire activity in climate conditions. As a result of the study, it is seen that there is an overall increase in the number of fires while the burned area decreases. Out-of-control behaviors in control graphs are not in a continuous trend but sometimes exceed the control limits. This condition is seen to be positive as a trend but also points to the possibility of unexpected annual burned area and the number of fires.

**Keywords:** Forest fire, statistical quality control, number of fire, burnt area

1. Introduction

Fires are natural events that frequently occur around Mediterranean Region and are mainly caused by the flammable vegetation with high aridity and over-temperatures in summers. The changes in weather conditions such as air temperature, relative humidity, wind speed, precipitation being of great importance on huge forest fires cause significant impacts on forest fire behaviors (Martell *et al.*, 1987; Sağlam & Bilgili, 2000; Kıcük & Sağlam, 2004; Westerling *et al.*, 2006; Kasischke & Turetsky, 2006). Another factor being important for fires is that summers are long-lasting periods with hot and dry weather in spite of warm and rainy winters. The changes in climate factors are also observed in this region as in all around the world. It was identified that there was an increase in aridity and temperature in the eastern coasts of Spain located in the west of the Mediterranean Region according to 1910-1994 meteorological records. In addition to these climate changes in the same area, there was an increase in fire activity from 1968 on owing to other several factors (Pinollet *et al.*, 1998). Hantson et al. had similar results in their study and determined that there is a strong relationship between fire sizes at global level and human activities as well as precipitation and aridity (Demir *et al.*, 2008; Hantson *et al.*, 2015). The changes in European land use in the Mediterranean Region and flammable matters also cause
the changes in fire activity and fire regimes. Abandonment of agricultural lands in rural areas and such areas consequently getting fire sensitive forests and scrublands also impact on fire activity (De Dios et al., 2007). Depending on the increasing population, the Mediterranean surroundings with expanding residential area have become an extremely fire sensitive region in all Southern and Eastern Europe (Darques, 2015). It is clear that the increase in human activity as a socio-economic factor is also an influential factor for the fire trend. In a research study carried out for the Western Mediterranean Region in Europe, the existence of more abundant flammable matters due to the today’s land use compared to that before 1970 results in more fires in numbers that lead to huge burned areas. This situation is becoming much worse with the increasing aridity (Velez, 1982; Pausas & Munoz, 2011; Lelieveld et al., 2012; Schilling et al., 2012). According to the estimations of HadAMP3 model in which the future climate conditions are investigated, it was estimated that the temperatures will increase 5-6°C out of the coastal regions and face up to 8°C increases across the country in summer time (Demir et al., 2008).

In Turkey having a coastal line in the Mediterranean, risks for fire is expected to increase owing to both vegetation & climatic reasons and human-induced climate change with some other socio-economic reasons. Almost half of the total forest area in the country is constituted by fire sensitive tree species (in a total of 10.434.441 ha with calabrian pine in 5.420.525 ha, black pine in 4.202.298 ha, maritime pine in 77.092 ha, stone pine in 42.618 ha and various oak species in 691.878 ha) (Forestry Statistics OGM-I, 2009). In the Aegean and Mediterranean Regions in Turkey exist fire sensitive calabrian pines and various maquis elements as the dominant vegetation. The dominant tree species is calabrian pine between 0-1400m in these regions and might be mixed with oak at low altitudes and black pine at high altitudes (Forest Atlas, 2009).

The Mediterranean Region covering all Southern Europe, Turkey, the Mediterranean coasts of the Middle East is one of the regions that will be mostly influenced by the global change all around the world (Giorgi and Lionello, 2008). The majority of fires in Turkey are human-induced and there is an upward tendency in temperature because of the global climate change and urbanization but a downward tendency in precipitation especially in the western and southern parts of Turkey where the Mediterranean precipitation regime is dominantly seen (Türkeş, 2012).
2. Material And Methods

2.1 Material

The study area is of Turkey’s general forest lands and the forests of Çanakkale, İzmir, Muğla and Antalya Regional Directorates of Forestry. The fire data used for this study is from Directorate General of Forestry including from 1988 to 2015. The determined dates were identified considering the data quality and the graphs showing the number of fires and burned area according to the data are given in Figure 2. The most fires in the last 27 years were seen in 2013 in Turkey and there was an increasing trend in the number of fires except for 1994. The burned area hitting the top in 2008 reached to highest values in 1994, 2000 and 2008.

![Figure 2. Number of Fires and burned area (ha) in Turkey](image)

While Turkey had a bad season in 1994 in terms of the number of fires, there was an adverse situation in Antalya region. The number of fires later came to a head towards 2013 and the burned area, in a similar trend, reached a record level in 2008. It is considered that the most arid two years successively in 2007 and 2008 had an effect upon these results. It is observed that there is a downward trend in terms of both the number of fires and burned area in Çanakkale Region contrary to other study areas. This trend was apparent in the number of fires and reached to top in the amount of burned area in every 6-8 years. In İzmir Region, there was a significant decrease in the amount of burned area despite the increase in the number of fires in Muğla, Antalya region and across Turkey.

2.2 Method

In this research study, the trends of burned area and number of fires in Antalya, Çanakkale, İzmir and Muğla forestlands along with the countrywide were analyzed via the statistical quality control method which is used in many disciplines and scientific activities. Control charts such as Shewart charts and cusum (cumulative sum control chart) are made use of in evaluating the trend and distribution of the process in this method and if the process is out of the control limits, the problematic factors are tried to be eliminated (Montgomery, 2009; Oakland, J.S., 2007). In a research carried out Northwestern Ontario in 2007 with the use of statistical quality methods, it was determined by Podur et al. (2002) that there was serious increases in the number of fires and burned area over time. In the statistical analyses of this study was used R programming language.
3. Results

27-year control charts (1988-2015 period) were made for Antalya, Çanakkale, İzmir and Muğla Regions along with countrywide charts in Turkey. These control charts consist of Shewart and CUSUM mean (X) charts and Shewart Standard deviation (S) charts. It is seen that the upper control limit was exceeded in 2013 in xbar and S charts made for the number of fires and in S chart in terms of the burned area in 2013 in Turkey (Figure 3). Moreover, it is also seen that the upper control limit, according to S chart, was exceeded because of a huge fire that burned an area of 22.133,5 ha (Kantarçi, 2009) in Antalya-Taşağıl in 2008 (the largest fire ever since 1938 in Turkey).

A considerably stable trend is seen in Antalya Region. The number of fires went below the lower control limit 1997-1998 and the burned area showed a moderate progress during the entire research process but later deviated from the normal progress due the big fire in 2008. This deviation is all seen in X, cusum and S charts (Figure 3). In the chart of the number of fires for Çanakkale Region, a stable trend goes within the control limits; however, the one for burned area comes to a head at times. In cusum (cumulative sum control) chart (Montgomery, 2009) developed for the points which Shewart charts are apathetic to, it is seen that upper and lower control limits are seen to be exceeded unlike in X chart. A downward trend in the number chart towards the recent years is seen to exceed the lower limit. On the other hand, a stable trend is observed in standard deviation chart. The burned area values for Çanakkale Region are seen not to exceed the control limits (Figure 3).
In İzmir Region, the values of the number of fires and burned area exceeded in neither xbar nor standard deviation charts. However, despite a stable trend seen in xbar and S charts for the number and area, a more sensitive cusum chart showed increases and decreases. The year of 1994 in which the burned area exceeded the control limits stands out (Figure 4). When analyzed the reasons of high values in 1994 for İzmir Region, it was identified that this year had the highest value with 28.32°C among the average summer temperatures from 1980 to 2011 and had a precipitation below average with a summer rainfall of 6.84mm. The analyses of charts belonging to Muğla Region show that each of three charts values (xbar, S and cusum) remained within the control limits but exceeded the upper limits in 1996 for the burned area (Figure 4). It is thought that Çetibeli fire burning 7000ha and Söke fire burning 1438ha played a role in exceeding the control limits of the burned area charts in 1996, an important year for Muğla. Also, the average summer temperature in Muğla, 23.09°C, was exceeded in 1996 (23.46°C).

4. Results And Discussion

SQC methods are one of the statistical methods used in a production system, healthcare organization or with a purpose of revealing the trend of natural disasters. The trend is determined according to the lower and upper limits exceeding in the charts and the measures are set according to this trend.
Figure 5. Shewhart control and Cusum control charts of $X$ and shewhart chart of $S$ for number of fires and burned area in Turkey

In Turkey and Antalya charts of the study, it was pointed out that 2008 went out of control by exceeding the upper limits in Antalya in terms of the burned area and by exceeding the upper limits in Turkey in terms of the number of fires in 2013 (Figure 5, Figure 6). When 1994 is disregarded, the last 10 years stands out in exceeding the upper limits also important as the number and area. Although exceeding the upper limits is more important for us, determining the measures to be taken also play an important role as well as lower control limits for reliable predictions.
Figure 6. Shewhart control and Cusum control charts of X and shewhart chart of S for number of fires and burned area in Antalya

Exceeding the limits is considered to be getting out of control. In spite of occasional peak trends, the trend of burned area is of an overall downward tendency, but an overall upward tendency despite an undulant trend in terms of the number of fires. Until today, the fire in Antalya-Taşağıl that occurred in 2008 is statistically the largest fire ever since. Yet, the data shows that the amount of burned area has been in a constant downward trend since then.
Fig. 7. Shewhart control and Cusum control charts of X and shewhart chart of S for number of fires and burned area in Canakkale.

Besides the increase in the number of fires in İzmir Region, it is seen that İzmir with the burned area, Çanakkale with the number and area, Muğla with the number and burned area are of a downward or stable trend (Figure 7, 8, 9). This situation reveals that a downward trend in the number of fires and burned area has existed in the last 27 years for these 3 regions.
Despite the general optimistic situation, there exist a risk of burning of large areas due to the climate change conditions caused by an upward trend in the temperatures of summer months for western & southern regions in Turkey and a downward trend in both total annual precipitation and summer precipitation along with the socio-economic factors (Türkeş, 2012; Demir et al., 2008; Giannakopoulos et al., 2011; San-Miguel-Ayanz et al.,
Here stands out the importance of such affairs as various technological innovations, many simulation programs and modeling, local mobile meteorological stations, firefighting planning and fire management practices and several maintenance activities like pruning against fires or prescribed burning (Yavuz et al., 2015; Küçük &
Sağlam, 2004). Therefore, the tracking of fire trends and regimes plays a significant role with regular changes to be carried out in Turkey.

References

1. Akkaş ME, Bucak C, Boza Z, et al. 2008, Aegean Forestry Research Institute, Technical Bulletin No: 36, İzmir.
2. Baş R, 1965, Türkiye’de Orman Yangınları Problemi Ve Bazı Klimatik Faktörlerin Yangınlara Etkileri Üzerine Araştırmalar. İÜ Orman Fakültesi Dergisi, Series A, Vol 15, No2.
3. Benneyan JC, 1998, Statistical quality control methods in infection control and hospital epidemiology, Part II: Chart use, statistical properties, and research issues. Infection control and hospital epidemiology, 265-283.
4. Brotons L, Asquith N, De Cáceres et al, 2013, How fire history, fire suppression practices and climate change affect wildfire regimes in Mediterranean landscapes. PLOS one, 8(5), e62392.
5. Darques R, 2015, Mediterranean cities under fire. A critical approach to the wildland–urban interface. Applied Geography, 59, 10-21.
6. Demir I, Kiç G, Coşkun M, et al. 2008, Türkiye’de maksimum, minimum ve ortalama hava sıcaklıkları ile yağış dizilerinde gözlenen değişiklikler ve eğilimler. TMMOB Ilklim Değişimi Sempozyumu Bildiriler Kitabı, 69-84.
7. Demir I, Kiç G and Coşkun M, 2008, PRECIS Bölgesel İklim Modeli İle Türkiye İçin İklim Öngörülerı: HaDAMP3 Sres A2 Senaryosu. Atmosfer Bilimleri Sempozyumu, Bildiriler Kitabı, 365-373.
8. Filipe AF, Lawrence JE and Bonada N, 2013, Vulnerability of stream biota to climate change in mediterranean climate regions: a synthesis of ecological responses and conservation challenges. Hydrobiology, 719(1), 331-351.
9. Giorgi F and Lionello P, 2008, Climate change projections for the Mediterranean region. Global and planetary change, 63(2), 90-104.
10. Hantson S, Pueyo S, and Chuvieco E, 2015, Global fire size distribution is driven by human impact and climate. Global Ecology and Biogeography, 24(1), 77-86.
11. Kantarcı D, 2009, Taşağı – Serik (Antalya) orman yangını (31.7.2008 – 4.8.2008) ve sonrasında öngörülen işlemler üzerine ekolojik değerlendirme. Orman Mühendisliği Dergisi, Yıl: 46, Sayı 1-3, ISSN 1 301-3572 (33-37)-Ankara.
12. Karali A, Hatzaki M, Giannakopoulos C, et al, 2014, Sensitivity and evaluation of current fire risk and future projections due to climate change: the case study of Greece. Natural Hazards and Earth System Sciences, 14(1), 143-153.
13. Kasischke ES and Turetsky MR, 2006, Recent changes in the fire regime across the North American boreal region—spatial and temporal patterns of burning in Canada and Alaska. Geophysical research letters, 33(9).
14. Koutsias N, Xanthopoulos G, Founda D et al. 2013, On the relationships between forest fires and weather conditions in Greece from long-term national observations (1894–2010). International Journal of Wildland Fire, 22(4), 493-507.
15. Küçük Ö and Sağlam B, 2004, Orman Yangınları ve Hava Halleri. Gazi Üniversitesi Orman Fakültesi Dergisi. Kastamonu, 4(2), 220-230.
16. Leliaveld J, Hadjimicolau P, Kostopoulou E, et al. 2012, Climate change and impacts in the Eastern Mediterranean and the Middle East. Climatic Change, 114(3-4), 667-687.
17. Martell DL, Otkul S and Stocks BJ, 1987, A logistic model for predicting daily people-caused forest fire occurrence in Ontario. Canadian Journal of Forest Research, 17(5), 394-401.
18. Martell DL, 2017, Climate change extending forest fire season in Ontario & Alberta, researcher finds, viewed July 17 2014, http://www.cbc.ca/news/canada/thunder-bay/thunder-bay-forest-fires-climate-change-1.4198485
19. Montgomery DC, 2009, Statistical Quality Control (Vol. 7). New York: Wiley.
20. Oakland JS, 2007, Statistical Process Control. Routledge.
21. Organ A and Gürbüz T, 2012, Hastanelerde enfeksiyon alanlarının belirlenmesine yönelik istatistiksel kalite kontrol çalışması. Pamukkale Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, Sayı 13, 2012, Sayfa 43 - 54.
22. Pausas JG and Fernández-Muñoz S, 2012, Fire regime changes in the Western Mediterranean Basin: from fuel-limited to drought-driven fire regime. Climatic Change, 110(4), 215-226.
23. Piñol J, Terradas J and Lloret F, 1998, Climate warming, wildfire hazard, and wildfire occurrence in coastal eastern Spain. Climatic Change, 38(3), 345-357.
24. Podur J, Martell DL and Knight K, 2002, Statistical quality control analysis of forest fire activity in Canada. Canadian Journal of Forest Research, 32(2), 195-205.
25. Resco de Dios V, Fischer C and Colinas C, 2007, Climate change effects on Mediterranean forests and preventive measures. New forests, 33(1), 29-40.
26. Rodbard D, 1974, Statistical quality control and routine data processing for radioimmunoassays and immunoradiometric
assays. Clinical chemistry, 20(10), 1255-1270.
27. Sağlam B and Bilgili E, 2000, Fire occurrence in relation to weather conditions. IUFRO XXI World Congress.
28. Schilling J, Freier KP, Hertig E, et al. 2012, Climate change, vulnerability and adaptation in North Africa with focus on Morocco. Agriculture, Ecosystems & Environment, 156, 12-26.
29. Tedim F, Xanthopoulos G and Leone V, 2014, Forest Fires in Europe: Facts and Challenges. Wildfire Hazards, risks, and disasters, Edition: 1st, Chapter: 5, pp.77-99.
30. Türkeş M, Bedia J, Di Liberto F, et al. 2016, Decreasing Fires in Mediterranean Europe. PLoS one, 11(3), e0150663.
31. Türkeş M, 2012, Türkiye’de görülen ve öngörülen iklim değişikliği, kuraklık ve çölleşme. Ankara Üniversitesi Çevre Bilimleri Dergisi 4 (2): 1, 32.
32. Environment and Forestry Ministry, 2009, Forestry Statistics of Turkey, Ankara, Turkey.
33. Environment and Forestry Ministry, 2009, Forest Atlas, Ankara, Turkey.
34. Climate change and wildfires, viewed May 23 2016, https://www3.epa.gov/climatechange/science/indicators/ecosystems/wildfires.html
35. Wildfires and Climate Change, viewed May 23 2016,https://www.c2es.org/science-impacts/extreme-weather/wildfires
36. Wildlife Guide, viewed May 23 2016, https://www.nwf.org/Wildlife/Threats-to-Wildlife/Global-Warming/Global-Warming-is-Causing-Extreme-Weather/Wildfires.aspx
37. Wildfires: A Symptom of Climate Change, viewed May 23 2016, https://www.nasa.gov/topics/earth/features/wildfires.html
38. Extreme weather events are the new normal, viewed July 17 2017, https://www.nature.com/news/extreme-events-are-the-new-normal-1.22516
39. Velez R, 1982, Forest fires in the Mediterranean region. In Forest Fire Prevention and Control (pp. 37-51). Springer Netherlands.
40. Yavuz M, Saglam B, Kucuk O, et al. 2015, Assessing fuel load and fireline intensity in Bayam forest district, Turkey using Flam Map software and remote sensing techniques. In International forest fire conference in Black Sea Region (pp. 6-8).
41. Westerling AL, Hidalgo HG, Cayan DR, et al. 2006, Warming and earlier spring increase western US forest wildfire activity. Science, 313(5789), 940-943.