# THE ANALYSIS OF LARGE FIRE INCIDENCE IN TURKEY

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**Abstract**

The average of 21902 hectares area has been burned in 1198 fires annually from 1937 to 2009 in Turkey. Fires constitute the biggest risk for the forests in Turkey. Despite the all kinds of technological opportunities and equipment, under the effect of climate changes and various social factors, large fires burning large areas still happen. In short-term, it is predicted that, under the effect of global climate change, forest fires problem will grow. This study compares the number of fires and the land burned in fires larger than 300 ha between 1973 and 2009. In addition, estimations are made by using Markov method in order to predict the possibility and size of large fires in the next years. The results indicate that, especially in the fire-sensitive forests in the southern and western regions of Turkey, there is a big risk in terms of forest fire.

**Key words:** Forest fires, large fires, number of fires, burned area, Markov chains

## 1. Introduction

In recent years, large fires are frequently seen in other Mediterranean countries, as well as in Turkey. Despite that the number of large fires is low, they are responsible for the most part of burned areas (Stocks et al., 2002; Gillett et al., 2004). In year 2003, 5 large fires in France constituting 93% of total area burned and 450000 ha forest fire in Portugal in year 2003, and the forest fires in Greece (2007) and Guadalajara – Spain (2005) are the examples of those forest fires (Pereira et al., 2005; Rigolot and Alexandrian, 2006; Xanthopoulos, 2010; Viegas and Caballero, 2009; San-Miguel-Ayanz et al., 2013). Large fires, reasons of which vary between the regions, are the complex natural events shaped with cooperation of physical, climatic, and social conditions (Canton-Thompson et al., 2008). Rural area population density, urbanization, changes in land use, recreational use, flammable material, socioeconomic conditions, and intentional fires can be examples of those reasons (Pausas and Fernández-Muñoz, 2012; Lloret et al., 2002; Velez, 2001; Başaran and Sarıbaşak, 2008; Vayda, 1999; Çanakçıoğlu, 1993). A study on large fires in Canada carried out between 1959 and 1997, the reasons have been found to be the seasonality, the fire size and the frequency (Stocks et al., 2002). But another important reason of the worldwide proliferation of the large fires in recent years is the weather conditions and climate change (Flannigan et al., 2006; Westerling et al., 2006; Westerling, 2008).

While the prevalence of the large fires in Turkey was 7-15 years, large fires occurrence interval in alpine regions in Australia is 50-100 years and 4 years in Alaska (GDF-1, 2010; Williams et al., 2008; Kasischke et al., 2002). Being a natural element for Mediterranean region with evolutional and paleoecological data, the fires have shown significant increase in 20$^{th}$ century in terms of number and area burned (Pausas et al., 2008; Pausas and Vallejo, 1999). In the fire that has burned 20.217,6 ha

(largest forest fire of Turkey) of area in Antalya-Taşağıl region in 2008, the presence of block forests, the redundancy of young stands, and the increase in temperature in recent years have led that fire to reach at that size (Kantarcı, 2009; Başaran and Sarıbaşak, 2008).

In this study, we examined the importance and the regional and numeric distribution of the large fires in Turkey and aimed to estimate the trend in last 40 years and the situation in future.

**2. Material and Method**

In this study, the large fires larger than 300 ha in Turkey between 1973 and 2009 have been examined, and the projections about the prevalence and date of this kind of forests have been made by using Markov chains method under the light of previous data. The year 1973 has been selected as beginning because the previous large fire data are not clear.

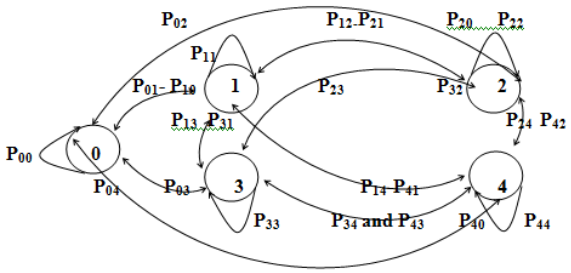


Fig. 1 Conceptual representation of Markov Chain model of large fires.

Markov chains state a class of probabilistic process at broad-spectrum applications. In addition, Markov chains allow the modeling of transition probabilities by matrices (Spedicato and Signorelli, 2014). Markov chain is a method that is widely used in estimating natural events such as precipitation and drought trend (Bahadır and Özdemir, 2011; Koçak and Şen, 1997) or earthquakes (Yücemen and Akkaya, 1995; Can et al., 2013; Özel and Solmaz, 2012). Markov chains have been utilized also in estimating the forest fires (Silva et al., 2011) and examining the large fires (Mendes et al., 2010).

Figure 1 presents a conceptual representation of a first-order Markov chain model of large fires. To simplify the presentation, only five states are used here (0: no-large fire, 1: between the range of 300-500 ha, 2: between the range of 500-1000 ha, 3: between the range of 1000-2000 ha and 4 : >2000 ha). In this model, at each time step, large fire probabilistically evolves. For example, $P_{01}$ corresponds to the probability of transitioning from no-large fire level to a fire in the between the range of 300-500 ha, and so forth.

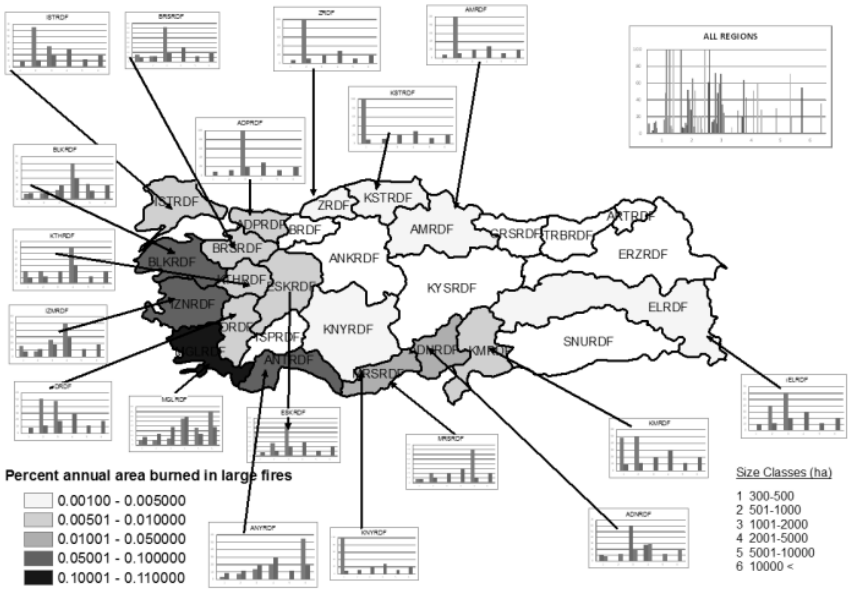


Fig.2. Percent of the area burned and number in large fires between 1973- 2009 by regional directorates and Turkey-wide

**3. Results and Discussion**

**3.1 Evaluation of Large Fires**

When the large fires are examined, it is seen that, in 37 years between 1973- 2009, there have been 174 large fires on 300 ha of land. In those 176 fires, a total area of 172.2 thousand ha has been burned. When the area that large fires have burned is examined, Muğla ranks by far the first region in terms of the area burned and is followed by Balıkesir, Antalya, İzmir and Adana, respectively (Fig. 2). In distribution of fires in Turkey between the years 2000 and 2009, first 5 ranks in terms of annual area burned belong to Antalya (2633 ha), Muğla (1232 ha), İzmir (1125 ha), Balıkesir (822 ha), and Çanakkale Regional Forest Directorates (716 ha). In 10-year averages calculated before the year 2008 Muğla region has the highest value of area burned, while the large fire in Antalya, where 20.217,6 ha of area has been burned in year 2008, has conveyed Antalya to first rank.

In Figure 2 the percent of the annual average area burned is shown on a map. Also, the distribution of large fires by class is shown in the graphic. Here the breakdown of large fires in each regional directorate that occurred between the years 1973-2009 is given in numbers according to 6 classes. Accordingly, it is found that, in Antalya, Muğla and Mersin regional directorates, 4$^{th}$, 5$^{th}$ and 6$^{th}$ class fires are seen, while 1$^{st}$, 2$^{nd}$ and 3$^{rd}$ class large fires occur in other regions, where the area burned annually is lower.

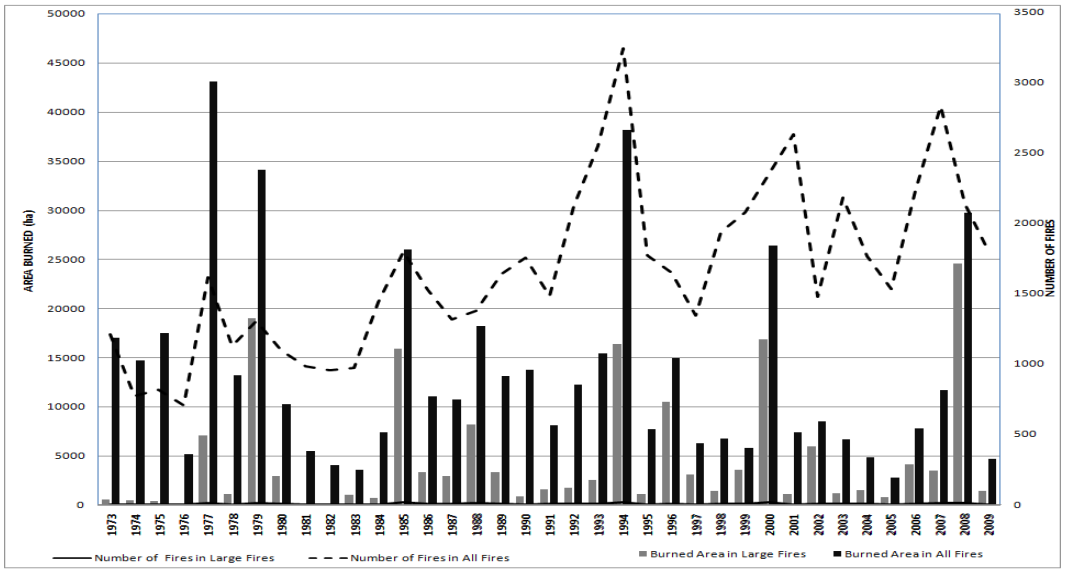


Fig.3. The area burned and large fires between 1973 and 2009

Examining the entire Turkey, it has been determined that 55.24% of all the large fires have occurred in Antalya, İzmir and Muğla regions (Ertugrul and Varol, 2015). Large fires in Turkey occur mostly in August, and it is followed by July. During 37 years examined within the scope of this study, it has been seen that no area larger than 300 ha has been burned in Turkey in January and November months. July, August and September are the most risky months in terms of large fires. Among the regions, where the highest number of fire is observed, it has been determined that 97% in number and 96% in area of fires in Mediterranean region and 84% in number and 94% in area of fires in Aegean region are seen in July, August and September (Varol and Ertugrul, 2015).

Since spring months are mostly rainy, these months do not allow the occurrence of large fires and thus, although there are less large fires in May compared to winter months, it is interesting that in April, which is also a spring month, 9 large fires have been seen. That 6 of these 9 fires have occurred in 2000s. Another interesting thing is that 20 of these 176 fires occurred in 2007, 2008 and 2009 and 55 of them occurred in the 2000s. These values indicate that the rate of occurrence of large fires have increased gradually since 2000. Regarding the total area burned, although there are some peak points (1977, 1979, 1985, 1994, 2000, 2008), 2008 has been the worst year in terms of the total area that fires have burned (Fig. 3). It can be thought that both of various socio-economic factors and the climate changes in Turkey could have an effect on this situation.

**3.2 Markov chain probabilities**

Markov chain transition matrix belonging to the data between the years 1973-2009 are as follows:

$$P = \begin{bmatrix} 0.005 & 0.493 & 0.493 & 0.005 & 0.005 \\ 0.023 & 0.522 & 0.204 & 0.182 & 0.068 \\ 0.000 & 0.509 & 0.396 & 0.057 & 0.038 \\ 0.000 & 0.280 & 0.439 & 0.160 & 0.120 \\ 0.000 & 0.634 & 0.182 & 0.182 & 0.000 \end{bmatrix}$$

When 2, 3, 4 and 5 shift series for Markov chain model are calculated, it is seen that very small differences (0.3%) occur for each series. Even the result has the values very similar to state matrix, and the likelihood of occurrence of size classes are as follows: $P_1=[0.017 \quad 0.470 \quad 0.284 \quad 0.152 \quad 0.078]$

According to the model solution, Possibility of large fire after another large fire is 47% for the size of 300-500 ha; 28.4% for the size of 500-1000 ha, 15.2% for the size of 1000-2000 ha, and 7.8% for the larger than 2000 ha.

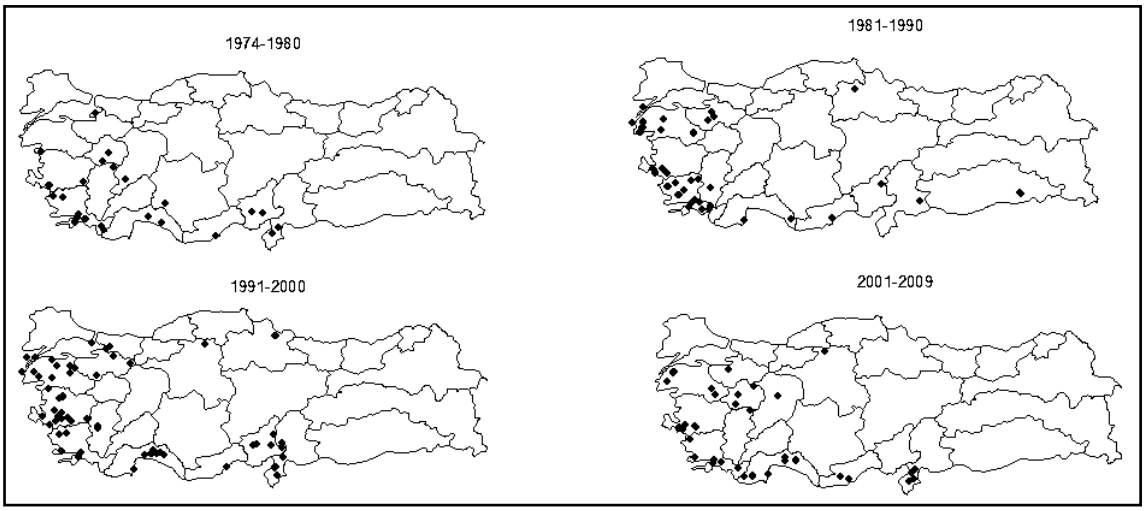


Fig. 4. Large fire locates between 1973 and 2009 by regional directorates in Turkey.

In addition, the highest number of large fires in Turkey occurred in 1994 (18 fires), 2000 (16 fires) and 1985 (14 fires), respectively. When Markov chain model has been used for those three years, it has provided the best result for the estimation of fire group that could give a rise after 2nd and 3rd group fire. The model was not successful in estimating the possibility of the break out of 2nd, 3rd and 4th group fires after a 1st group fire; and a 4th group fire after a 4th group fire.

**4. Conclusions**

In large fires in Turkey, the area burned per fire has increased from 550 ha in 1970s to 1006 ha in 1985, 850 ha in 1990s, and then reached at 960 ha in 2009. But in Portugal, while the area burned per fire has been 430 ha in early 1980s, this value has increased to 454 ha in further years, and reached 635 ha in early 21st century (Tedim et al., 2014).

The years 1977, 1994, 2008, 2000, and 1985 are the years, in which the largest lands have been burned within 37 years examined within the scope of this research. Therefore, there is a 7-8 year cycle between the largest areas burned. In a study on large fires in Portugal, although there was not an obvious trend between the size of burned areas every year and the risk of large fires, a cyclic period of three years has been found about the extreme fires (Mendes et al., 2010). We found 6-9 years cycle period between large fires in Turkey (Fig. 3). Forest fire data in Portugal was analyzed using Markov chain and at the end of the study, it was found that between the years 1980-2006 there was an increasing trend in the area burned (Silva and Dias, 2013). 1994 was the worst year in Turkey, and the highest number of large fires between 1974 and 2009 occurred in period of 1991-2000 (Fig.4). Except the year 1994, the worst fire seasons are 2007, 2001, 1993, 2000, 2006, 2003, 2008, 1992 and 1999. When the large fires are examined, it is seen that there has been 176 large fires and 172.2 thousand ha of

land has been burned. One thing that stands out about large fires is that, during the years in which large fires occurred and burned large areas, there is an increase in the area burned in proportion to other years. Not only socio-economic factors but also warming and decreasing trend in spring-summer rainfalls could have an effect on this increase (Pausas·and Fernández-Muñoz, 2012; Lloret et al., 2002; Velez, 2001). Increase in extreme weather conditions all around the world will cause to an increase in large fires (Flannigan et al., 2006; Westerling, 2008). Therefore, it will be right to make a change in the system which extinguish and eliminate all small fires and thus, cause to accumulation of inflammable materials (Arno and Allison Bunnell, 2002; Chandler et al., 1991; Omi, 2005). Especially in forests with high risk of fire in the western and south of Turkey, using controlled burning actively and widely can be an effective method in fighting against large fires (Neyişçi, 1989). Another thing that should be considered here is to monitor the fire regime and climate changes in Turkey. Thus, that will give us an idea about whether there will be a need for renewing the forest fire struggling policies in Turkey or not and in such a case, and what kind of changes will be made.

**References**

Arno, S. F. and Allison-Bunnell, S. *Flames in our forest: disaster or renewal?*. Island Press.227p. (2002).

Bahadır, M. and Ozdemir, M.A.: Trabzon ve Rize'de Yağışın Mevsimsel Değisimlerinin Marginal ve Matrix Yöntemleri ile Belirlenmesi ve Trend Analizleri. The Journal of International Social Research. cilt: 4 sayı: **17** (2011).

Başaran, M.A. and Sarıbaşak, H.: Serik-Taşağıl Orman Yangını Durum Tespit Raporu. GDF (2008).

Can, C.E., Ergun, G. and Gokceoglu, C.: Bilecik Çevresinde Deprem Tehlikesinin Saklı Markov Modeli ile Tahmini.2. Türkiye deprem mühendisliği ve sismoloji konferansı 25-27 Eylül 2013 – MKÜ – Hatay (2013).

Canton-Thompson, J., Gebert, K.M., Thompson, B., Jones, G., Calkin, D. and Donovan, G.:External Human Factors in Incident Management Team Decision Making and Their Effect on Large Fire Suppression Expenditures, Journal of Forestry, 416-424 page (2008).

Chandler, C., Cheney, P., Thomas, P., Trabaud, L., and Williams, D. *Fire in forestry. Volume 1. Forest fire behavior and effects. Volume 2. Forest fire management and organization*. John Wiley & Sons, Inc. (1983).

Çanakçıoğlu, H.: Orman Koruma, Üniversite Yayın No:3624, Fakülte Yayın No:41.1, ISBN 975-404-199-7, İstanbul (1993).

Ertugrul, M. and Varol, T. The relationship between fire number and burned area in Antalya, Izmir and Muğla regions in Turkey. *Journal of Environmental Biology*, **36**(2) (2015).

Flannigan, M. D., Amiro, B. D., Logan, K. A., Stocks, B. J., and Wotton, B. M. Forest fires and climate change in the 21st century. *Mitigation and adaptation strategies for global change*,**11**(4), 847-859 (2006).

GDF-1: 2009 yılı Yangın Eylem Planı, Ankara, Turkey (2010),

Gillett, N. P., Weaver, A. J., Zwiers, F. W., and Flannigan, M. D. Detecting the effect of climate change on Canadian forest fires. Geophysical Research Letters, 31(18), (2004).

Kantarcı, D., 2009. Orman Mühendisliği Dergisi Yıl 46, **sayı 1, 2, 3 (Ocak, Şubat, Mart)** 2009 ISSN 1 301-3572 (33-37)

Kasischke, E.S., Williams, D. and Barry D. Analysis Of The Patterns Of Large Fires In The Boreal Forest Region Of Alaska. International Journal of Wildland Fire, **Vol. 11** Issue 2, p131, 14p. (2002).

Koçak, K. and Sen, Z. Kurak ve Yağışlı Gün Oluşumlarının Markov Zinciri Yaklaşımı İle Uygulamalı İncelenmesi. Tr. J. of Engineeringand Environmental Science **22**: 479 - 487 (1997).

Lloret, F., Calvo, E., Pons, X., and Díaz-Delgado, R. Wildfires and landscape patterns in the Eastern Iberian Peninsula. *Landscape Ecology*, **17**(8), 745-759 (2002).

Mendes, J., Cortes Bermudez, P. Z., Pereira, J., Turkman, F. K. and Vasconcelos, P. M.: Spatial Extremes Of Wildfire Sizes: Bayesian Hierarchical Models For Extremes. Environmental and Ecological Statistics, **17(1)**:1–28 (2010).

Neyişçi, T. Kızılçam orman ekosistemlerinde denetimli yakmanın toprak kimyasal özellikleri ve fidan gelişimi üzerine etkileri. *Ormancılık Araştırma Enstitüsü Müdürlüğü* (1989).

Omi, P.N. *Forest Fires: A Reference Handbook*. Contemporary world issues, ABC-CLIO, 347p. (2005).

Ozel, G. and Solmaz, A. Turkiye'de Deprem Tekrarlanma Zamanının Tahmini Ve Neotektonik Bölgelere Göre Depremselliğinin Markov Zinciri İle İncelenmesi. Çankaya Uni. J. of Science and Engineering, **Volume 9**, 2: 125-138 (2012).

Pausas, J. G., and Vallejo, V. R. The role of fire in European Mediterranean ecosystems. In *Remote sensing of large wildfires* (pp. 3-16). Springer Berlin Heidelberg, (1999).

Pausas, J.C., Llovet, J., Rodrigo, A. and Vallejo, R. Are Wildfires A Disaster In The Mediterranean Basin? -A Review International Journal of Wildland Fire, **Vol. 17** Issue 6, p713-723, 11p. (2008).

Pausas, J. G. and Fernández-Muñoz, S. Fire regime changes in the Western Mediterranean Basin: from fuel-limited to drought-driven fire regime. *Climatic change*, **110** (1-2), 215-226 (2012).

Pereira, M.G.,Trigo, R.M., Da Camara,C.C., Pereira, J.M.C. and Leite, S.M. Synoptic Patterns Associated With Large Summer Forest Fires In Portugal. Agricultural and Forest 24. Meteorology, **Volume 129**, Issues 1-2, Pages 11-25 (2005).

Rigolot, E. and Alexandrian, D. Learning From Fuel-Break Behaviour During The 2003 Large Fires In South Eastern France. Forest Ecology and Management, **Vol 234**, p 227 (2006).

San-Miguel-Ayanz, J., Moreno, J. M., and Camia, A. Analysis of large fires in European Mediterranean landscapes: lessons learned and perspectives. *Forest Ecology and Management*, *294*, 11-22 (2013).

Silva, J.,S., Vaz, P., Moreira, F., Catry, F. and Rego, F.C. Wildfires As A Major Driver Of Landscape Dynamics In Three Fire-Prone Areas Of Portugal. Landscape and Urban Planning, **101**: 349–358 (2011)

Silva, G., L. and Dias, M.I. Modelling And Analysis Of Forest Fire Data In Portugal- Part II (Report). NotasE Comunicações 18/12, Centro de Estatística e Aplicações da Universidade de Lisboa (2013).

Spedicato G. A. andSignorelli M. The Markov Chain Package: A Package For Easily Handling Discrete Markov Chains In R, Submitted To The Journal of Statistical Software (2014).

Stocks, B., Mason, J.A., Todd, J.B., Bosch, E.M., Wotton, B.M., Amiro, B.D., Flannigan, M.D., Hirsch, K.G., Logan, K.A., Martell, D.L. and Skinner, W.R. Large Forest Fires In Canada, 1959–1997. Journal of Geophysical Research, **Vol. 108**. No. D1, 8149, doi:10.1029/2001JD000484. (2002).

Tedim, F., Remelgado, R., Martins, J.and Carvalho, S. The Largest Forest Fires in Portugal: The constraints of burned area size of the comprehension of fire severity*, Journal of Environmental Biology*, **36** (Special issue), 133-143(2015).

Varol, T. and Ertugrul, M. The Impact of the Changing Climate on Fire Activity in Muğla Region. *Polish Journal of Environmental Studies*, **24**(3) (2015).

Vayda, A. P. *Finding causes of the 1997-98 Indonesian forest fires: problems and possibilities*. WWF Indonesia (1999).

Vélez, R. Causes of forest fires in the Mediterranean Basin. In Risk management and sustainable forestry. EFI Proceedings (Vol. 42, pp. 35-42), (2002).

Viegas, D. X. and Caballero, D. The accident of Guadalajara 2005. Recent Forest Fire Related Accidents in Europe, 3-17, (2009).

Yücemen S. and Akkaya A. A comparative study of stochastic models for seismic hazard estimation. In: El-Sabh MI, Venkatesh S, Denis H, Murty TS, editors. Land-Based and Marine Hazards: Scientific and Management Issues, Series on Advances in Natural and Technological Hazards Research. pp. 5–24, (1995).

Westerling, A. L., Hidalgo, H. G., Cayan, D. R. and Swetnam, T. W. Warming and earlier spring increase western US forest wildfire activity *science*, **313**(5789), 940-943 (2006).

Westerling, A. L.. Climate and Wildfire in the Western United States, California Applications Program White Paper, Climate Research Division, Scripps Institution of Oceanography. (2008).

Williams, R.J.,Wahren, C.H., Tolsma, A.D., Sanecki, G.M., Papst, W.A., Myers, B.A., McDougall, K.L., Heinze, D.A. and Gren, K. Large Fires In Australian Alpine Landscapes: Their Part In The Historical Fire Regime And Their Impacts On Alpine Biodiversity. International Journal of Wildland Fire, **Vol. 17** Issue 6, p793-808, 16p.(2008).

Xanthopoulos, G. Examining the causes of large forest fires in Mediterranean countries. In *proceedings of the international workshop on "Assessment of Forest Fire Risks and Innovative Strategies for Fire Prevention* (pp. 4-6) (2010).