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Effect of Slope on the Analysis of Forest Fire Risk

Orman Yangını Riskinin Analizinde Eğimin Etkisi

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ABSTRACT

Forest fires are mainly caused by human activities. Therefore, the forest fire risk in an area is under the influence of human activities that may cause forest fires if the vegetation and topographic features are also suitable. While evaluating the effect of slope on forest fire risk in our study, It has been analyzed with geographical information systems (GIS) the starting points of forest fires have occurred in Turkey in the last 10 years. Thus, an objective assessment try to has been made about the effect of slope on forest fire risk. According to the analysis results, 40.53% of forest fires occur in Turkey the range of 0-10% slope. In addition, 87.16% of these fires occur at 0-30% slope. As a result, contrary to the general belief, it has been determined that as the slope increases, the risk of forest fire decreases. The slope affects the fire inversely proportional, On the other hand, it affects the forest fire danger in direct proportion.

Key Words

Forest fire risk, risk index, slope, GIS.

ÖZ

Orman yangınlarının ana sebebi insan faaliyetleridir. Bu nedenle bir alanda orman yangını riski, eğer bitki örtüsü ve topoğrafik özellikler de uygunsa, orman yangınına sebep olabilecek insan faaliyetlerinin etkisindedir. Çalışmamızda eğimin orman yangını riskine etkisi değerlendirilirken, son 10 yılda Türkiye'de meydana gelmiş orman yangınlarının başlangıç noktaları coğrafi bilgi sistemleri (CBS) ile analiz edilmiştir. Böylece eğimin orman yangını riskine etkisi konusunda objektif bir değerlendirme yapılmaya çalışılmıştır. Analiz sonuçlarına göre Türkiye'de orman yangınlarının %40,53'ü %0-10 eğim aralığında meydana gelmektedir. Ayrıca bu yangınların %87,16'sı %0-30 eğimde meydana gelmektedir. Sonuç olarak, genel kanıya zıt bir şekilde, eğim arttıkça orman yangını riskinin azaldığı tespit edilmiştir. Eğim orman yangını riskini ters orantılı olarak etkilerken orman yangını tehlikesini ise doğru orantılı olarak etkilemektedir.

Anahtar Kelimeler

Orman yangını riski, risk indeksi, eğim, CBS.

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INTRODUCTION

The increasing direct and indirect impact of human activities on today's fire regimes makes it difficult to predict future fire regime changes [1]. The impact of fires as an ecological factor may result in an ongoing reconstruction process of ecosystems after fire [2], as well as resulting in degradation of the ecosystem due to human causes or distancing from existing floristic composition and structural features [3]. In other words, both climate change [4] and other anthropogenic changes [5] significantly change regional fire regimes [6]. Therefore, when human and human activities are involved, forest fire can turn into a major disaster that needs to be evaluated outside the natural cycle.

Causes of 89% of forest fires in Turkey while human-induced activities, only 11% are due to lightning [7]. Based on this information, areas with high risk of forest fire are places where fire can easily start and where human activities get closer to the forest. For example, most forest fires in Turkey start from agricultural areas, residential areas, power lines, roads and railways, mining areas, dumps and picnic areas, in or near the forests [7]. All of these areas are places where people and human activities are intense.

It is an obvious fact that the success of forest fire organizations that do not benefit from Decision Support Systems such as GIS will be limited and expensive [8]. The most effective decision support systems to be used in combating forest fires; are the forest fire risk and forest fire danger prediction systems that form the basis of the resource organization [9,10]. A precise evaluation of forest fire problems and decisions on solution methods can only be satisfactorily made when a fire risk zone map is available. [11].

Almost in all previous studies, slope has been considered as a criterion that directly affects both forest fire risk and forest fire danger. However, risk and danger are different concepts. The fact that the slope criterion was evaluated with the same criteria for both analyzes caused this study to be carried out.

Forest fire risk is the possibility of occur a forest fire due to various human activities or due to a natural cause such as lightning. Forest fire risk is high in places such as roads, agricultural areas, picnic areas where human activities are diverse and intense in the forest, but low in places where human activities are not intense in the same forest [12]. Forest fire danger is the danger posed by the thick and lively flammable community, which increases the severity of fire and creates extinguishing difficulties with thin dry combustibles that can easily ignite. Forest fire danger increases due to the amount of fine dry combustibles, where fires first start, easily ignite and are consumed completely in the fire. Meteorological and topographic parameters are directly effective on fire danger [12].

If all of the forest fire risk factors, including lightning, that can cause a fire can eliminate, forest fire danger is also eliminated. In this case, fire danger cannot be mentioned [13]. So, the slope criterion; In the analysis of the forest fire risk, it should be evaluated in terms of the impact on the diversity and intensity of human activities in or near the forest, while in the analysis of the forest fire danger, it should be evaluated in terms of the effect on the speed of spread, the type and amount of flammable material, and the fire severity.

PREVIOUS STUDIES

In the analyzing of the forest fire risk, static indices based on criteria such as topography, vegetation type and distance to human activities are used. However, dynamic indices with criteria such as temperature, wind and humidity are also used in the analysis of forest fire danger. Complex indices used for both risk and danger analysis were also tried (Table 1).

It was stated that as the slope increases in all of these studies, both the forest fire risk and the forest fire danger increase. Tables and equations were prepared in accordance with this rule, and risk and danger indices were calculated accordingly (Table 2).

Table 1. Criteria and indices used in previous studies.

Type of Analysis	Criteria	Index	Reference
Risk	Vegetation, altitude, slope, aspect, distance to road	Static	Chuvieco and Congalton (1989) / Spain
Risk	Vegetation type (fuel moisture), slope, distance to settlement, distance to road	Static	Jaiswal et al. (2002) / India
Danger	Temperature, humidity and precipitation	Dynamic	Alonso- Betanzos et al. (2002) / Spain
Risk	Vegetation type (fuel moisture), slope, aspect, distance to roads and distance to settlements	Static	Erten et al. (2002) / Turkey
Risk	Forest type (species), slope, aspect, distance to road, distance to settlement	Static	Erten et al. (2005) / Turkey
Risk	Species composition, crown closure, development stage, aspect, slope, agricultural area-forest distance, distance to settlement	Static	Saglam et al. (2008) / Turkey
Danger	Species composition, crown closure, development stage, aspect, slope	Static+Dynamic	Saglam et al. (2008) / Turkey
Risk	Vegetation (fuel moisture), slope, aspect, distance to roads and settlements	Static	Siachalou et al. (2009) / Greece
Danger+Risk	Fuel model, solar radiation, topographic humidity and population density	Static+ Dynamic	Lein and Stump (2009) /USA
Risk	Roads, buildings, land use, slope, altitude and view	Static	Cipriani et al. (2011) / Brasil
Risk	NDMI (Normalized Difference Moisture Index), slope, aspect, altitude, distance to roads, distance to settlements	Static	Adab et al. (2013) / Iran
Risk	Species combination, crown closure, development stage, slope, aspect, distance to settlements and agricultural areas, distance to roads	Static	Sivrikaya et al. (2014) / Turkey

Table 2. Use of slope criteria and calculation of risk / danger index in previous studies

Slope	Value Assigned	Risk/Danger	Equation	Reference
0-3%	2	Low Risk	FR=10F+2H+2R+3S FR: Forest fire risk index F: Vegetation type H: Distance to settlements R: Distance to road S: Slope	Jaiswal et al. (2002) / India
3-5 %	3	Moderate Risk		
5-10 %	4	Moderate Risk		
10-15 %	5	High Risk		
15-35 %	6	Very High Risk		
>35%	10	Very High Risk	RC = 7FT+5(S+A)+ 3(DR+DS) RC: Forest fire risk index FT: Vegetation type S:Slope A:Aspect DR:Distance to road DS:Distance to settlements	Erten et al. (2002) / Turkey
< 5 %	1	No Risk		
10-5 %	2	Low Risk		
25-10 %	3	Moderate Risk		
35-25 %	4	High Risk		
> 35 %	5	Very High Risk		
0-5 %	1	Low Risk	FRI=10SC+2AL+2SA+ 3S+2IS FRI: Forest fire risk index SC: Species composition AL: Distance to agricultural areas SA: Distance to settlements S: Slope IS: Aspect	Saglam et al. (2008) / Turkey
5-15 %	2	Moderate Risk		
15-35 %	3	High Risk		
>35 %	5	Very High Risk		
< 5 %	1	No Risk	FRI = 7Vt+5(S+A)+ 3(Dr+Ds) FRI: Forest fire risk index Vt: Vegetation type S:Slope A:Aspect Dr: Distance to road Ds: Distance to settlements	Adab et al. (2013) / Iran
10-5 %	2	Low Risk		
25-10 %	3	Moderate Risk		
35-25 %	4	High Risk		
> 35 %	5	Very High Risk		
0-5 %	1	Low Danger	FDI=SC^2(CC+SD+S+IS) FDI: Forest fire danger index SC: Species composition CC: Crown closure SD:Stage of development S: Slope IS: Aspect	Saglam et al. (2008) / Turkey
5-15 %	2	Moderate Danger		
15-35 %	3	High Danger		
>35 %	5	Very High Danger		
0-5 %	1	Low Risk	FRI=10(SC+CC+DS) +5S+3IS+2SA+2R FRI: Forest fire risk index SC: Species composition CC: Crown closure DS: Developement stage S: Slope IS: Aspect	Sivrikaya et al. (2014) / Turkey
5-15 %	2	Moderate Risk		
15-35 %	3	High Risk		
>35 %	5	Very High Risk		

MATERIALS and METHODS

The likelihood of a forest fire largely depends on the presence and intensity of human activities, and human activities are mostly concentrated in low slope areas. For example, 81% of villages in Turkey were established in areas with a slope of 0-20% [14]. Therefore, the risk of forest fire should be high in low slope areas. In order to test this determination, in the last 10 years (2010-2019) occurred forest fires in Turkey, were analyzed with GIS.

Data

The data stored on fire registry forms for many years started to be gradually stored in the computer system after 1998. With the "Fire Management System" that started to be used after 2010, more and more healthy information has been kept in the database. Today, as soon as each forest fire is detected, is entered a web-based management system, and a maximum of 64 different information about each fire can be stored in the database based on GIS. However, not all fires have fire starting data.

In the last 10 years (2010-2019) 24.773 forest fires have occurred in Turkey. While 2,725 of these fires were caused by lightning, 22,048 were caused by human activities. There are starting coordinate data of 7,766 of 22,048 fires caused by human activities [15]. The slope analysis was made on these fires, where starting data are available.

Method

7,766 forest fires with fire starting data were analyzed with GIS using a digital topography map base. The slope percentages of the fire-starting coordinates were determined and a ratio-based table was created, thus, it was tried to reveal in which range the forest fires occurred the most according to the slope.

To make the results more meaningful, firstly, distribution of Turkey's forests on the slope classes were analyzed. Thus, the proportional distribution of forest fire risk on the Turkey's forest areas is also shown.

RESULTS and DISCUSSION

All studies on the forest fire risk have accepted that the slope has a linear effect on fire risk [11,16-23]. However, approximately 90% of forest fires are caused by people and human activities. People also prefer low slope lands as much as possible for settlement and work. Because as the slope increases, both costs and labor increase [14]. In other words, human and human activities, which are the biggest cause of forest fire, are concentrated in low slope areas.

When the fire-starting points are analyzed with GIS, it is seen that 40.53% of forest fires started in areas with a slope of 0-10%. Also 23,57% of fires occurred in areas with a slope of 11-20% and 7,09% of the fires occurred in areas with a slope of 21-30% (Figure 1). In other words, 87,16% of fires started in areas with a slope of 0-30%. On slopes above 50%, it is understood that forest fire rarely begins. In contrast, only 46,12% of the forests in Turkey is located on the slopes of 0-30%. (Table 3).

Table 3. Slope analysis of forest fires in the last 10 years (2010-2019) in Turkey.

Slope (%)	Number of Fires	Rates (%)	Forest Area (%)
0-10	3147	40,53	18,56
11-20	2530	32,57	16,23
21-30	1092	14,06	11,33
31-40	551	7,09	13,63
41-50	247	3,19	10,91
51-60	124	1,59	8,22
61-70	48	0,62	6,45
71-80	17	0,22	6,24
81-90	7	0,09	4,12
>91	3	0,04	4,31
TOPLAM	7.766	100,00	100,00

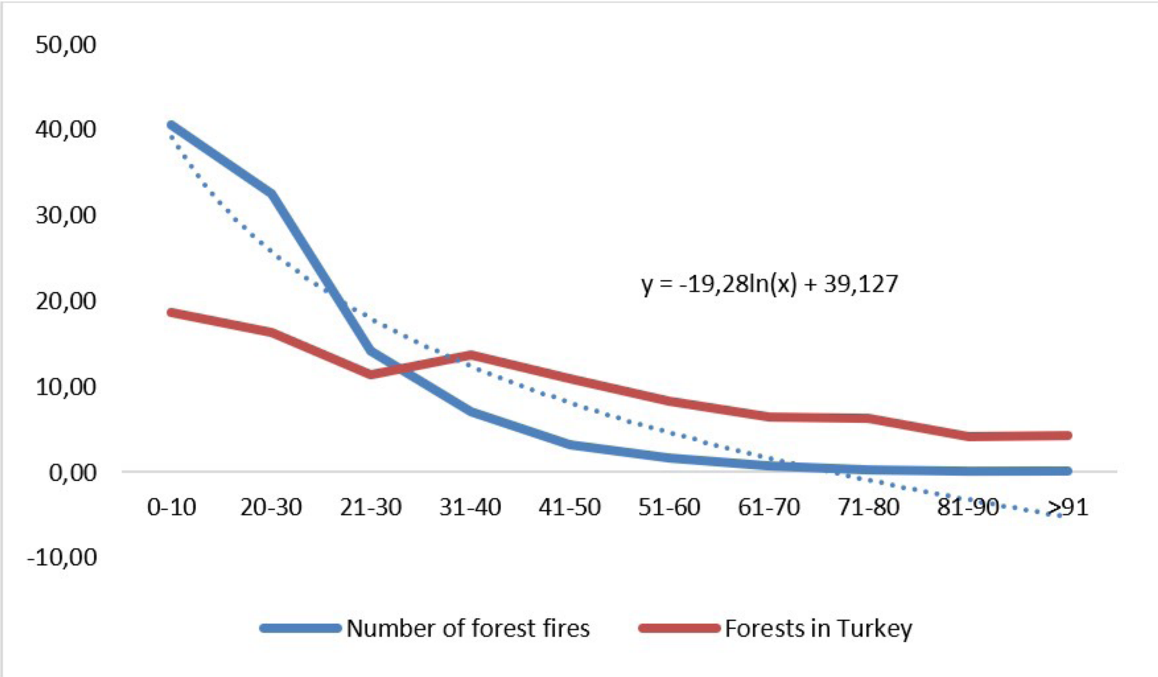

Figure 1. Forest fires and Forests in Turkey on the slope ranges.

In previous studies, it was accepted that the forest fire risk increases with slope, just like the forest fire danger. Therefore, the slope is included in the equation as a criterion that increases the risk when calculating the forest fire risk index (Table 2). As a result of this relatively objective study, a new classification for slope-forest fire risk has been revealed (Table 4).

CONCLUSION

Slope is one of the most important factors affecting the forest fire danger. Assuming there is no wind, the flames and heat increase depending on the slope. In a study was conducted in 1997, Teie stated that the speed of fire spread on a 50% slope land is equal to a wind with a speed of 8 km per hour [24,25]. On the other hand, Perry stated in his study in 1990 that every 20% increase in slope doubled the rate of fire spread [26]. The slope degree has almost the same effect as the wind on the growth of fires. This effect; It can be explained as “fires progress faster on sloping terrain provided that other features are the same” [24].

However, contrary to what is mentioned in previous studies; while the forest fire danger increases with slope, the forest fire risk decreases as the slope increases.

Forest fire risk indicates the possibility of to occur forest fire in an area. The main cause of forest fires is human activities. People also prefer to settle, work and continue other activities on low slope lands where they are advantageous in terms of energy and cost.

Table 3. Effect of slope criterion on forest fire risk and risk rating.

Slope (%)	Value Assigned	Risk
0-10	5	Very High Risk
11-20	4	High Risk
21-30	3	Moderate Risk
31-50	2	Low Risk
>50	1	Very Low Risk

Geographic analysis of the starting coordinates of a large number of forest fires suggests that the slope criterion may have been misused in all studies on forest fire risk so far.

As a result of our study, it is thought that the risk classification that reveals the slope-forest fire risk relationship can be used for more accurate evaluations in the analysis of fire risk.

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References

1. S. Archibald, C.E.R. Lehmann, J.L. Gómez-Dans, R. A. Bradstock, Defining pyromes and global syndromes of fire regimes, Proceedings of the National Academy of Sciences, 110 (2013) 6442-6447.
2. M.A. Doussi, C.A. Thanos, Postfire regeneration of hardseeded plants: Ecophysology of seed germination, Proceedings of the 2nd International Conference of Forest Fire Research, Coimbra, 25 (1994) 1035-1044.
3. Y. Birot (ed.), Living with Wild fires: What science can tell us, A contribution to the science–Policy dialoque, EFI Discussion Paper, 15 (2009) 53-58.
4. J. G. Pausas, Changes in fire and climate in the eastern Iberian Peninsula (Mediterranean basin), Climatic Change, 63 (2004) 337-350.
5. J. G. Pausas, J. E. Keeley, Abrupt climate-independent fire regime changes, Ecosystems, 17 (2014) 1109-1120.
6. Ç. Tavşanoğlu, Yangın coğrafyası: Vejetasyon yangınlarının ve ekolojik sonuçlarının alansal dağılımı, Kebikeç, 43 (2017) 289-300.
7. Ogm(a), 2010-2019 yılları arasında meydana gelen orman yangınlarının çıkış sebeplerine dağılımı, Orman Yangınları Değerlendirme Raporu, OGM Orman Yangınlarıyla Mücadele Daire Başkanlığı, (2020) 48.
8. E. Bilgili, B. Sağlam, E.Z. Başkent, Yangın amenajmanı planlamalarında yangın tehlike oranları ve coğrafi bilgi sistemleri, Fen ve Mühendislik Dergisi, 4 (2001) 88-97.
9. B.W. Van Wilgen, R., E. Burgan, Adaptation of The United States fire danger rating system to fynbos conditions, part II, Historic fire danger in the Fynbos biome, South African Forestry Journal, 129 (1984) 66-78.
10. S.W. Taylor, M. E. Alexander, Considerations in developing a national forest fire danger rating system, paper presented at the XII World Forestry Congress, Quebec, Canada, 2003.
11. R.K. Jaiswal, S. Mukherjee, D.K. Raju, R. Saxena, Forest fire risk zone mapping from satellite imagery and GIS, Int Journal of Applied Earth Observation and Geoinformation, 4 (2002) 1-10.
12. T. Neyişçi, Y. Ayaşlıgil, T. Ayaşlıgil, T. Sönmezışık, Yangına dirençli orman kurma ilkeleri, Tubitak-Togtag-1342, TMMOB Orman müh. Odası yayınları, 21 (1999).
13. H. Çanakçıoğlu, Orman Koruma ders kitabı, İ.Ü. Orman Fakültesi yayınları 1993.
14. S. Hayli, F.A. Canpolat, Türkiye'de kırsal yerleşmelerin kuruluş ve gelişmesinde etkili olan faktörlere teorik bir yaklaşım, Zeitschrift Für Die Welt Der Türken, 10 (2018) 183-206.
15. Ogm(b), Son 10 yıllık (2010-2019) yangın sıralacı, Orman yangınlarıyla mücadele daire başkanlığı veri tabanı, OGM Orman Yangınlarıyla Mücadele Daire Başkanlığı, 2020.
16. E. Erten, V. Kurgun, N. Musaoglu, Forest fire risk zone mapping from satellite ımagery and GIS: A case study, Proceedings of XX.th Congress of ISPRS, Turkey, (2004) 12-25.
17. E. Erten, V. Kurgun, N. Musaoğlu, Uzaktan algılama ve coğrafi bilgi sistemleri kullanarak orman yangını bilgi sisteminin kurulması, Proceedings of TMMOB harita ve kadastro mühendisleri odası 10. Türkiye harita bilimsel ve teknik kurultayı, 2005.
18. B. Sağlam, B. Ertuğrul, B.D. Durmaz, A.İ. Kadıoğulları, Ö. Küçük, Spatio-temporal analysis of forest fire risk and danger using LANDSAT imagery, Sensors, 8 (2008) 3970-3987.
19. H.N. Cipriani, J.A.A. Pereira, R.A. Silva, S.G. Freitas, L.T. Oliveira, Fire risk map for the Serra de São Domingos Municipal Park, Poços de Caldas, CERNE, 17(1) (2011) 77-83.
20. H. Adab, K.D. Kanniah, K. Solaimani, Modeling forest fire risk in the northeast of İran using remote sensing and GIS techniques, Nat Hazards, 65 (2013) 1723-1743.
21. F. Sivrikaya, A.E. Akay, H. Oğuz, N. Yenilmez, Mapping forest fire danger zones using GIS: A case study from Kahramanmaraş, 6th International Symposium on Ecology and Environmental Problems, 17-20 November, Antalya, Turkey (2011).
22. M. Karabulut, A. Karakoç, M. Gürbüz, Y. Kızılelma, Determination of forest fire risk areas in Başkonuş Mountain (Kahramanmaraş) using geographical ınformation systems, Int Soc Res J., 6 (2013) 171-179.
23. A.E. Akay, H. Şahin, Forest Fire Risk Mapping by using GIS Techniques and AHP Method: A Case Study in Bodrum, Turkey, Eur J Forest Eng, 5(1) (2019) 25-35.
24. 24.P.L. Andrews, C.H. Chase, Fire behavior prediction and fuel modeling system. USDA Forest Service, General Technical Report INT-260, Utah, 1989.
25. C.W. Teie, Fire officier's handbook on wildland firefighting, Deer Valley Press Rescue, California, 1997.
26. D.G. Perry, Wildland firefighting. Fire behavior, tactics and command. Fire Publications, Inc. California, 1990.