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What do forest firefighters think about organization and infrastructure problems in combating large forest fires?

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Abstract: The occurrence of large forest fires (LFFs) arises from the interaction of various factors, notably including climate change, meteorological conditions, fuel accumulation, and deficiencies in organization and infrastructure. In Türkiye, many LFFs occurred in Antalya and Muğla Regional Directorates of Forestry in 2021. This study aims to evaluate whether problems arising from organization and infrastructure had an impact on the growth of LFFs. A total of 621 forest fire workers, drivers, and operators (FWDs), actively involved in combating the LFFs, responded to survey questions using a nine-point Likert-type scale. Statistical differences in responses were analysed using the Mann-Whitney U test. The study's results indicate that problems stemming from personnel employment, the amount of construction equipment, the quantity of aircraft, fire suppression infrastructure, communication and coordination, and occupational health and safety have a moderate impact on the growth of forest fires. Since long-term and uninterrupted work causes inefficiency in LFFs, 52% of FWDs consider a working duration of 1-3 days adequate for LFFs. A statistical difference between the evaluations of two groups for 13 different factors presented in the study was found only in terms of the lack of personnel in the fire trucks and ground teams. In the fight against forest fires, the strength of land crews and the infrastructure support—such as water resources and forest roads—are just as important and effective as the use of technological tools like aircraft, fire trucks, and construction machinery.
Keywords: Climate change, Fire suppression, Forest fire organization, Megafire, Perception

Orman yangın işçileri, büyük orman yangınlarıyla mücadelede örgütlenme ve altyapı sorunları hakkında ne düşünüyor?

Öz: İklim değişikliği, meteorolojik koşullar, yakıt birikimi, organizasyon ve altyapı eksiklikleri gibi faktörler, büyük orman yangınlarının oluşumunu etkilemektedir. Türkiye'de 2021 yılında Antalya ve Muğla Orman Bölge Müdürlüklerinde çok sayıda büyük orman yangınlarını meydana gelmiştir. Bu çalışmada, büyük orman yangınlarının büyümesinde organizasyon ve altyapıdan kaynaklanan sorunların etkili olup olmadığını değerlendirmek amaçlanmıştır. Büyük orman yangınlarıyla mücadelede aktif olarak görev almış toplam 621 orman yangını işçisi, şoförü ve operatörü, dokuz noktalı Likert tipi bir cevaplama ölçeği kullanılarak anket sorularını yanıtlamıştır. Orman yangın işçileri ile şoför ve operatörlerin yanıtları arasındaki istatistiksel farklılıklar, Mann-Whitney U testi kullanılarak analiz edilmiştir. Çalışmanın sonuçları, personel istihdamı, iş makinası sayısı, hava araçlarının sayısı, yangın söndürme altyapısı, iletişim ve koordinasyon ile iş sağlığı ve güvenliğinden kaynaklanan sorunların büyük orman yangınları üzerinde orta düzeyde bir etkiye sahip olduğunu göstermektedir. Uzun süreli ve kesintisiz çalışma, verimsizliğe neden olduğundan, işçi, şoför ve operatörlerin %52'si 1-3 günlük çalışma süresinin büyük orman yangınlarında yeterli olduğunu düşünmektedir. Çalışmada sunulan 13 farklı faktör için iki grubun değerlendirmeleri arasında sadece arazöz ve yer ekiplerindeki personel eksikliği açısından istatistiksel fark bulunmuştur. Orman yangınlarıyla mücadelede, hava araçları, arazöz, iş makinesi gibi teknolojik araçların kullanımı kadar yer ekiplerinin gücü ve altyapı olanakları (su kaynakları, orman yolları vb.) da önemli ve etkilidir.
Anahtar kelimeler: İklim değişikliği, Yangın söndürme, Orman yangını organizasyonu, Mega yangın, Algı

1. Introduction

Approximately 4% of global vegetation is exposed to forest fires every year (FAO, 2022). In recent years, both the number of fires and the amount of area burned have increased significantly around the world. Areas with a Mediterranean climate are especially prone to fire, owing to the arid and temperate conditions, combustible vegetation, and increased human activities (Dimitrakopoulos et al., 2011). As such, all Mediterranean countries are faced with the problem of forest fires (Iliadis et al., 2002). Evolutionary and paleoecological studies show that fires are natural in the Mediterranean Basin (Pausas et al., 2008). However, Ganteaume et al. (2013) reported that almost all fires are human-caused and in the European Mediterranean region, most of them are caused deliberately. This trend has begun to change showing an increase of the fires due to negligence with the current land use-land cover change. Therefore, the traditional rural socio-economic systems that once characterized the Mediterranean region collapsed in the last few decades, resulting in a rural

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exodus in the northern part of the Mediterranean basin, and an overexploitation of natural resources in the eastern regions. In parallel, huge, rapidly occurring land-use changes have taken place, including urbanization of coastal areas with the development of tourism and the construction of infrastructures, which have created conflicts and additional driving factors of forest fires. The significant increase in the number of fires and the amount of burned areas in the 20th century caused the public to perceive fires as disasters negatively. Although the forest ecosystems of the Mediterranean Basin, including Türkiye, have the characteristics to cope with fire, these ecosystems have become highly sensitive to fire on account of both the increase in the number of fires and the destruction that they cause. Forest fires reduce the benefits produced by forest ecosystems and disrupt activities for society (Varela et al., 2014; Lecina-Diaz et al., 2021).

The vast majority of forest fires are easily controlled and very few areas are burned in these fires. As a matter of fact, according to FAO (2022) data, approximately 90% of forest fires in the world each year are easily controlled and the amount of area burned in these fires constitutes approximately 10% of the total annual amount of burned area. This data shows that current planning, management, and technologies work very well for easily contained fires (FAO, 2022). However, the situation is altogether different with large forest fires (LFFs), where their suppression abilities are insufficient (Tedim et al., 2018). Increasingly, LFFs in many parts of the world account for a disproportionately high percentage of the total amount of area burned (Attiwill and Binkley, 2013; Fernandes et al., 2016a; Fernandes et al., 2016b). In LFFs, which are a growing concern globally, ecosystems and habitats are transformed, human losses are experienced, and significant economic, social, and ecological damage occurs (Gill and Allan, 2008; Adams, 2013; San-Miguel-Ayanz et al., 2013; Fernandes et al., 2016b; Tedim et al., 2018).

There is no single, coherent, quantitative definition of LFFs that focuses principally on the size of the fire (Buckland, 2016; Tedim et al., 2018). To date, no widely accepted size threshold has been established for LFFs; only some values have been proposed (Tedim et al., 2018). For example, threshold values for LFFs in Europe are greater than 100 hectares (ha) according to some sources, while others are greater than 1,000 ha (Küçükosmanoğlu, 1986; Bilgili et al., 2010; Tedim et al., 2018). The threshold value in Canada and Russia is at least 200 ha (Gill and Allan, 2008), in Greece, it is at least 1,000 ha (Dimitrakopoulos et al., 2011), and in the US it is at least 40,000 ha (Pyne, 2007).

LFFs may result from a combination of factors, such as (i) the constant presence of forest fuel accumulation over a large area, (ii) the merging of two or more fires, (iii) the rapid rates of spread with the help of weather, fuel, and topography, (iv) a fire taking a long time to spread, (v) a failure in the initial suppression operations, and (vi) the difficulty of reaching the fire (Gill and Allan 2008; Fernandes et al., 2016b). If more than one LFF takes place in a region at once, firefighting resources may be strained, and additional resource support (personnel, equipment, vehicles, and aircraft) may be needed from other districts (Stavros et al., 2014; Tedim et al., 2020). In 2021, the numerous LFFs taking place simultaneously in Türkiye are an example of this situation. Owing to the inability of teams to respond to the LFFs that occurred in multiple areas at once, aircraft, water tankers, helicopter, hand crew, ground teams, and construction equipment were supplemented from other regions of Türkiye (GDF, 2021).

There is no universally accepted method of forest firefighting, as countries or regions differ in the level, composition, and organization of firefighting resources. Basic tools for combating fires include the combination, number, and strength of ground teams (professional, seasonal, and volunteer firefighters, fire truck and other vehicle capacities, adoption of new technologies, etc.), and the type and capacity of air resources (airplanes, amphibious water bombers, helicopters, etc.) (Tedim et al., 2020). In LFFs, the use of hand tools is limited, and construction machinery such as dozers is needed to build roads and firebreaks. In forests with low road density and high altitudes, the effectiveness of ground crews decreases (Bassi and Kettunen, 2008). For this reason, the construction of roads and water resources in combating forest fires is considered among the most important infrastructure activities (Tadesse and Seboko, 2013).

As the fireline intensity builds, the amount of water used to control the flames increases (Tedim et al., 2018). In this context, access to water resources has gained importance in forest firefighting. In Türkiye, 4,580 pools and ponds with a capacity of 700–2,000 tons have been established roughly every 4 km to shorten the water supply time of fire trucks and aircraft (Avcı and Korkmaz, 2021; GDF, 2022).

The length of the forest road network planned in Türkiye is 380,466 km and only 292,530 km (76.9%) of these roads could be built until 2022. A further 87,936 km (23.1%) of forest roads still need to be constructed (GDF, 2022). Until 1985, forest firefighting activities were carried out by land crews. After 1985, however, with the increase in road density, construction equipment began to be used, such as forest fire water trucks and dozers. Aircraft (helicopters and airplanes) have been used for forest firefighting since 1987 (Sayın et al., 2014). Within the scope of land crews in Türkiye, 2270 first responder vehicles, 1078 fire trucks, 281 water tankers, 182 dozers, 135 excavators, 258 graders, 128 trailers, 22 mobile repair vehicles, 569 motorcycles, and 4162 tractor-connectable water tankers are still being used in forest firefighting. There are 11453 workers in the forest fire organization. Of these workers, 1123 are involved in surveillance, 1034 are involved in communications, and 9296 are involved in response activities (GDF, 2021).

An efficient, high-quality communication network ensures good communication and coordination between fire prevention and suppression actors. If these activities are well organized, the first response time to fires can be reduced (Tadesse and Seboko, 2013). Communication during forest fires is generally conducted by radio. In Türkiye, there are 20,168 radios used as central, watchtower, vehicle, and handheld radios to fight forest fires (GDF, 2022).

Cooperation among countries and regions regarding firefighting, education, and information exchange is on the rise in LFFs (FAO, 2007). For example, many countries (Austria, Azerbaijan, Belarus, France, Georgia, Croatia, Iran, Spain, Israel, Kazakhstan, Moldova, Poland, Russia, Ukraine, and the US) provided aircraft support (15 airplanes and 21 helicopters) to Türkiye to suppress LFFs in 2021. Thus, in the fight against LFFs, a total of 88 aircraft were used, together with the 49 helicopters and three airplanes available in Türkiye (GDF, 2021).

Firefighting is a demanding, stressful, and dangerous operation (Tadesse and Seboko, 2013). As such, an accurate understanding of the fundamental dynamics of forest fires is vital to ensuring the efficiency of future fire management, and in minimizing adverse effects on communities (McCaffrey et al., 2013). On account of the complex interactions between ignition, fuel, weather, topography, and suppression efforts, it is crucial to characterize LFFs and understand the role of precursor factors (Fernandes et al., 2016a).

In recent years, the literature on forest fires has focused primarily on explaining forest fire parameters (Kalabokidis et al., 2002; Grünig et al., 2022), modeling hazards and risks (Withen, 2007; Lein and Stump, 2009; Güney et al 2016; Urbieta et al., 2019), fire behavior (Bilgili, 2003; Vakalis et al., 2004), forest fire suppression planning (Tsakalidis and Gitas, 2007), and in-service training of forest firefighters (Şafak et al., 2023). In addition, specific issues have also been studied, such as the weather and fuel conditions accompanying LFFs (Bilgili et al., 2010; Liu et al., 2013; Fernandes et al., 2016a), the characteristics and dimensions of LFFs (Dimitrakopoulos et al., 2011; Buckland, 2016; Tedim et al., 2018), the effect of climate change on vegetation, biomass, water flow, the amount of area burned, and fire frequency (Mouillot et al., 2002; Juang et al., 2022; Oncel Cekim et al.,2021), the relationship between fire season and fire severity (Parks and Abatzoglou, 2020), people's sensitivity to changes in forest fire prevention and their social preferences (Varela et al., 2014), and bureaucratic inefficiency in forest firefighting activities (Purnomo et al., 2021). In 2023, a detailed book has been published on forest fires in Türkiye, examining them in terms of ecological, biological, socio-economic, fire prevention, extinguishing, post-fire production-marketing and restoration (Kavgacı and Başaran, 2023).

As shown in the literature presented above, research on forest fires has mostly focused on issues such as danger, risk, behavior, and climate impact in the technical and physical dimensions of forest fires. However, the problems arising from a lack of organization and infrastructure are also highly important parameters in the formation, exacerbation, and management of LFFs. It has been observed that these parameters are not sufficiently examined in the existing literature. As McCaffrey et al. (2013) have stated, although forest fires are a biophysical process, fire management is a social process. For this reason, the thoughts, perceptions, and attitudes that personnel involved in suppressing forest fires have toward forest firefighting activities should also be taken into account (Şafak et al., 2023; Leone et al., 2023). According to Leone et al. (2023), the perceptions of firefighters participating in frontline activities seem to be an understudied subject overall. Because perceptions can be used to better understand the dynamics and behaviors of events and enhance control measures, the fact that this high-risk group has been studied so little compared to other groups is an important knowledge gap.

Dimitrakopoulos et al. (2011) found no specific factor that consistently differentiates large fires from smaller ones, supporting the hypothesis that any fire can grow under certain conditions. Various elements, such as the effectiveness of initial response planning, decision-making at dispatch centers, on-site coordination, and the training and motivation of personnel, play a crucial role in determining the efficiency of fire suppression efforts (Tedim et al., 2020). In Türkiye, forest fire suppression decisions are made by forest engineers serving as fire supervisors. However, Forest Workforces (FWDs) are directly or indirectly impacted by these decisions and management practices, either positively or negatively.

The experience of FWDs in fighting LFFs is an area that has been little researched. This study has been evaluated the impact of deficiencies in forest fire organization, infrastructure, and other related factors on the spread of large forest fires in Türkiye, based on the perspectives of FWDs. The FWDs who took part in combating the LFFs in 2021 have been analysed to determine the amount of personnel in different units, the situation of vehicles (construction machinery, helicopters, and aircraft), the firefighting infrastructure (the state of forest water resources and forest roads), the lack of communication and coordination, and the current situation in occupational health and safety. In light of this data, it was examined whether the problems arising from the lack of organization and infrastructure in Türkiye were instrumental in the growth of forest fires in 2021.

2. Materials and methods

2.1. Study area

Türkiye's forest assets are 23.36 million ha. Forests cover 29.9% of the country's surface area (GDF, 2024). Of these forests, 57% (12.49 million ha) are highly sensitive to fire (GDF, 2018; GDF, 2021). In Türkiye, 254 forest fires greater than 300 ha broke out between 1977 and 2021, and 345,772 ha of forest area was damaged in these fires. In examining the decade of fire data in Türkiye from 2012–2021, it was found that 27,150 fires broke out, the size of the area burned was 226,846 ha, and the area size per fire was 8.35 ha (GDF, 2021).

In 2021, the first of the 15 LFFs in Türkiye started in Manavgat, Antalya, on July 28, and the last was extinguished in Köyceğiz, Muğla, on August 12. Two FWDs were killed in these fires. Extensive agricultural and forest areas were damaged, many people were evacuated from hundreds of villages and towns by land and sea, and many buildings and animals were damaged. During this period, the Mediterranean region was especially affected by the dry weather, with 139,503 ha of forest area being damaged in the big fires. The most forest area burned occurred in Antalya (60,358 ha) and Muğla (43,100 ha) Regional Directorates of Forestry (RDFs) (GDF, 2021).

The study area (Antalya and Muğla RDFs, where LFFs broke out in 2021) is located in the Mediterranean region of Türkiye. The forest area (2.34 million ha) of these RDFs constitutes 10% of Türkiye's forest area (GDF, 2024). Most of the vegetation consists of red pine, sclerophyllous forests and maquis. In Antalya and Muğla RDFs, where the Mediterranean climate predominates, summers are hot and dry, and winters are warm and rainy (Bilgili et al., 2010). In Antalya and Muğla, the annual average temperature is 18.9 °C and 18,5 °C, respectively, average annual precipitation is 1039,8 mm and 861,9 mm, and the maximum temperature is 45 °C and 44,6 °C (TSMS, 2025).

2.2. Material

Most of the material for this study was obtained from the survey conducted in 2021 with FWDs who took part in combating the LFF in the Antalya and Muğla provinces in Türkiye. The survey form consisted of two parts and 19

questions. The first part included personal information, and the second part involved an evaluation of the LFFs. FWDs evaluated these fires in terms of the problems they experienced, such as the number of personnel (fire truck and ground crews), vehicle status (construction machinery, helicopter, and airplane), fire suppression infrastructure (state of forest water resources and forest roads), and lack of communication and coordination. In addition, occupational health was evaluated in terms of safety and working time. The study was approved by the Social and Human Sciences Research Ethics Committee of the Istanbul University-Cerrahpaşa, Türkiye with the decision dated 20/10/2022 and numbered 2022/242.

2.3. Method

The hypothesis developed for the study was defined as follows:

H_0: There is no significant difference between fire workers and drivers in their views on problems and deficiencies related to LFFs.

The number of FWDs to be interviewed in the study was calculated using the following formula (Equation 1), (Daşdemir, 2021):

$$n \geq \frac{N.p.q.Z^2}{[N.d^2+p.q.Z^2]} \quad (1)$$

where n is the sample size; N is the size of the population (N=9296 FWDs); p is the probability of being in the main population with a probability of 50% of the staff involved in the fight against LFFs in Antalya and Muğla in 2021 (p=0.5). q is the probability that will not be in the main population with a probability of 50% of the staff involved in the fight against LFFs in Antalya and Muğla in 2021 (q=0.5). Z is the confidence coefficient (1.96 at 95% confidence level); d is the accepted sampling error (0,05). The n value was calculated as 369. A survey was conducted with 621 workers who took part in combating the LFFs that occurred in Antalya and Muğla in Türkiye in 2021. 368 of these personnel were fire workers, and 253 were drivers (first response vehicle drivers, fire truck drivers, water tanker drivers) and operators (dozers, diggers, excavators, graders, lorries, trailers). Altogether, these personnel work in 67 Forest Enterprise Directorates.

The FWDs answered the questions following a nine-point Likert-type scale. On this scale, 1 signified very strongly disagree, 3 signified very little agreement, 5 signified moderately agree, 7 signified strongly agree, and 9 signified very strongly agree. Points 2, 4, 6, and 8 were intermediate values across the range of agreement and disagreement.

First, the data was analyzed for normality with the Kolmogorov-Smirnov test, but the data did not show a normal distribution. In the second stage, the Mann-Whitney U test was used. The Mann-Whitney U test is used to test whether rank is different between two independent nonparametric groups (Kalaycı, 2016). In this study, the Mann-Whitney U test was used to examine whether there is a statistical difference between the perspectives and perceptions of FWDs who participated in the LFFs that took place in Antalya and Muğla in 2021 on some issues. In this context, between these two groups, forest fire organization, infrastructure, number of personnel, condition of vehicles, etc. differences or similarities in the subjects were examined with the Mann-Whitney U test. These statistical analyses were made using SPSS.

3. Results

3.1. Participants' demographics

The descriptive statistics of FWDs participating in the study are presented in Table 1. Accordingly, 59% of the participants are fire workers, and 41% are drivers (operators). The youngest is 19, and the most experienced is 63 years old. The average age of FWDs is 40. When the education level is examined, 50% of them are primary and secondary school graduates, 42% are high school graduates, and 8% have associate and undergraduate degrees. In addition, 81% of the personnel are married, and 80% are seasonal (temporary) workers. The average professional experience is 13 years.
Around 27% of the FWDs who took part in combating the LFFs were the personnel of Antalya and Muğla RDFs, and 73% were assigned as part of the additional support force from 18 other RDFs.

3.2. Participants' opinions on inadequacies in combating LFFs and differences in these opinions

3.2.1. Participants' opinions on inadequacies in combating LFFs

The evaluation of the problems and deficiencies in combating LFFs according to the perspectives and perceptions of the personnel working in Antalya and Muğla RDFs during LFFs is given in Table 2. In terms of the number of personnel, the participants have classified the lack of personnel in the water tanker (D1) and ground crews (D2) in LFFs as moderate (5.97). Concerning the number of vehicles, i) the number of construction machinery (D3) is below the medium level (4.84); ii) the number of fire helicopters (D4) is moderate (5.10); and iii) the number of firefighting aircraft (D5) is moderate (5.17).

Regarding fire suppression infrastructure, i) the amount of in-forest water resources (D6) is moderate (5.18); and ii) the number of forest roads and maintained forest roads (D7) is moderate (5.64).

Concerning communication and coordination, i) problems due to lack of coordination (D8) are at a moderate level (5.61), and ii) lack of communication and coordination in night work (D9) is moderate (5.24) as well.

In terms of occupational health and safety, i) displacement and transportation problems (D10) are experienced at a moderate level (5.24) in night work; ii) fatigue and insomnia (D11) from overwork are experienced (7.16) due to the prolonged duration of the fire; iii) occupational health and safety problems (D12) are below medium level (4.81); and iv) the lack of training of firefighters (D13) is considered low (3.67).

3.2.2. Differences in participant views on inadequacies

It was investigated whether FWDs had similar views and perceptions on the issues presented in Table 2 regarding major forest fires. The Mann-Whitney U test was used to analyse whether there was a statistical difference between the responses of FWDs within the scope of the problems and insufficiencies experienced in the fight against LFFs

presented in Table 2. According to this test results, there is a significant difference between the responses of FWDs, regarding the lack of personnel in the fire truck teams (D1, p=0.018), and the lack of staff in the ground crews (D2, p=0.001). In addition, according to the Mann-Whitney U test results, vehicle status (D3, D4, D5), fire suppression infrastructure (D6, D7), communication and coordination (D8, D9), and occupational health and safety (D10, D11, D12, D13), there is no statistical difference between the two groups in terms of the answers given to the statements presented on the subject.

In combating LFFs, the maximum number of working days that can be worked without leaving the field is an average of five days (Table 3). In general, 52% of the FWDs find 1–3 workdays appropriate, while 26% state that they can work for seven or more workdays.

Table 1. Descriptive characteristics of participants

Characteristics	Fire worker		Driver		General	
	N	%	N	%	N	%
Frequency	368	59.26	253	40.74	621	
Age (Mean)		38.74		42.36		40.22
Min–Max age		19–63		24–59		19–63
18–35	135	36.68	31	12.25	166	26.73
36–50	179	48.64	187	73.91	366	58.94
50<x	54	14.67	35	13.83	89	14.33
Education						
Primary school	104	28.26	70	27.67	174	28.02
Secondary school	62	16.85	74	29.25	136	21.9
High school	170	46.2	93	36.76	263	42.35
Associate degree	27	7.34	13	5.14	40	6.44
Bachelor's degree	5	1.36	3	1.19	8	1.29
Marital status (N and %)						
Married	273	74.18	233	92.09	506	81.48
Single	95	25.82	20	7.91	115	18.52
Staff type (N and %)						
Permanent (Perpetual)	79	21.47	45	17.79	124	19.97
Seasonal (Temporary)	289	78.53	208	82.21	497	80.03
Years of work (Mean)		12.68		13.65		13.08
1–5	85	23.1	12	4.74	97	15.62
6–10	89	24.18	59	23.32	148	23.83
11–15	94	25.54	124	49.01	218	35.1
16–20	38	10.33	31	12.25	69	11.11
20<x	62	16.85	27	10.67	89	14.33

Table 2. The problems and deficiencies in combating LFFs

	Staff problems	Fire worker		Driver		General		Mann whitney U	
		M	SD	M	SD	M	SD	Z	P
	Personnel Number								
D1	Lack of personnel in the water truck teams	5.73	2.97	6.31	2.73	5.97	2.89	-2.359	0.018*
D2	Lack of staff in ground crews	5.63	3.02	6.45	2.66	5.97	2.90	-3.285	0.001*
	Vehicle Status								
D3	Lack of construction machinery	4.69	2.9	5.05	2.82	4.84	2.87	-1.598	0.11
D4	Lack of fire helicopters	5.08	2.99	5.12	3.07	5.1	3.02	-0.181	0.856
D5	Lack of firefighting aircraft	5.16	3.03	5.18	3.07	5.17	3.05	-0.123	0.902
	Fire Suppression Infrastructure								
D6	Lack of in-forest water resources	5.04	2.81	5.38	2.89	5.18	2.85	-1.490	0.136
D7	The number of forest roads and maintained forest roads	5.65	2.72	5.63	2.71	5.64	2.71	-0.104	0.917
	Communication and Coordination								
D8	Problems due to lack of coordination	5.59	2.7	5.64	2.8	5.61	2.74	-0.353	0.724
D9	Lack of communication and coordination in night work	5.2	2.76	5.3	2.83	5.24	2.78	-0.521	0.602
	Occupational Health and Safety								
D10	The problem of displacement and transportation in night work	5.2	2.8	5.36	2.83	5.26	2.81	-0.735	0.462
D11	Work inefficiency due to fatigue and sleeplessness, depending on the prolonged duration of the fire	7.04	2.52	7.35	2.31	7.16	2.44	-1.461	0.144
D12	Occupational health and safety problems	4.74	2.92	4.92	3.11	4.81	3	-0.735	0.462
D13	Lack of training of fire workers	3.66	2.78	3.69	2.93	3.67	2.84	-0.223	0.823

*: There are differences between groups (p≤0.05); M = mean; SD = standard deviation; D = deficiency

Table 3. The maximum number of workdays in combating LFFs

Working time (Workday)	Fire Worker		Driver		General	
	N	%	N	%	N	%
1–3	184	50.00	136	53.76	320	51.53
4–6	88	23.91	51	20.16	139	22.38
7–9	47	12.77	19	7.51	66	10.63
10–14	28	7.61	29	11.46	57	9.18
x>15	21	5.71	18	7.11	39	6.28
Average (SD)	4.92 (3.95)		5.21 (4.76)		5.04 (4.3)	
Mann-Whitney U Test	z=-0.687		p=0.492			

According to the Mann-Whitney U test results in Table 3, there is no significant difference (p=0.492) between the answers given by forest firefighters and drivers in terms of the maximum number of workdays they can perform in combating LFFs.

4. Discussion

According to the Agriculture and Forestry Council (AFC) (2019), the inability to create a sufficient number of firefighters in the fire truck and ground crews, and the inadequate physical characteristics of the workers, are stated as the main weaknesses in the fight against forest fires. Tedim et al. (2018) indicated that if a fire cannot be suppressed as a result of the inadequacy of local fire crews or the lack of training of the teams, an extreme forest fire disaster may ensue. This situation may lay the groundwork for forest fires to take hold in rough lands, where the intervention of forest fire teams from the outside is more hazardous and problematic. According to the study results (D1 and D2), it was determined that the lack of personnel in both the fire truck and ground crews had a moderate (5.97) effect on the growth of LFFs. The evaluations of the FWDs regarding the lack of personnel in the fire truck (p=0.018) and ground crews (p=0.001) differ from each other in terms of significance. This difference has arisen because drivers are more affected by the lack of personnel, and owing to the lack of personnel, some of the duties of FWDs are assigned to drivers as an additional task. Avcı and Korkmaz (2021) emphasized that although more FWDs were needed during the last 10 years, this number has decreased significantly over the last three years. In this context, the personnel problem can partially be alleviated by establishing and supporting the volunteer system expressed in GDF (2021).

The deficiency of construction machinery (D3) in the growth of LFFs is seen as a medium-level problem by firefighters (4.69) and drivers (5.05). The two groups agreed regarding the duty machine deficiency, and there was no statistical difference (p=0.110) between them. It is stated that dozers are required in the construction of firebreaks, which are essential in both strip openings and counter-fire applications in LFFs (Küçükosmanoğlu, 1986; Tadesse and Seboko, 2013).

Success in fighting forest fires requires a combination of ground and air firefighting forces (Dimitrakopoulos et al., 2011). Air support is highly effective in most forest fires, especially in the first response phase (Tedim et al., 2020). FWDs indicated that deficiency of D4 and D5 was moderately effective in the growth of LFFs (5.10 and 5.17, respectively). The two groups agreed on this issue, and there was no significant difference (p=0.856; p=0.902). However, the purchasing or leasing of aircraft in the fight against forest fires creates a great economic burden. In this context, Tadesse and Seboko (2013) suggest that aircraft should be used in other interventions (human, equipment, or food transportation in social events, such as natural disasters and conflict) to reduce these costs outside the fire season.

Water is generally used as the main suppression component in firefighting. Land and air crews are organized with vehicles that use from 400 liters to 10 tons of water with different levels of mobility (Tedim et al., 2020). According to FWDs, the deficiency of in-forest water resources (D6) had a moderate effect (5.18) in the growth of LFFs. On this issue, the two groups agreed, and there was no statistical difference (p=0.136) between them. Due to the limited water storage capacity of water tenders and aircraft in combating forest fires, water must be supplied from the nearest point as soon as possible. As such, establishing artificial or natural water resources in the forest is imperative in reducing the water supply time (Tadesse and Seboko, 2013; GDF, 2021). Tadesse and Seboko (2013) stated that the water in the water pools of the hotels located in and on the edge of the forest could be used with a motor pump to respond to forest fires around the hotel and supply water to the water tankers. This arrangement could also be used in detached buildings in and around the forest. For such structures, it may be necessary to have a water source with a motor pump in swimming pools or similar systems. As such, a self-defense mechanism can be established in the building to guard against the danger of forest fires.

Forest roads have many intended purposes, such as connecting settlements and providing access to residences and tourism facilities. According to FWDs, the number of forest roads and maintained forest roads (D7) are moderately effective (5.64) in the growth of LFFs. On this issue, the two groups agreed, and there was no significant difference (p=0.917) between them. It is important that bushes are cleared on and around the edge of forest roads (Tadesse and Seboko, 2013). Bilgili et al. (2010) stated that there is no road network, and the efforts to fight forest fires in neglected forest areas will be insufficient. Forest road maintenance should be performed before the fire season to shorten the time to reach the fire, and to reduce the effect of the roadside and the combustible material load on the fire. Kasap et al (2024) declareted to minimize the effects of forest fires on forest ecosystems, initial response teams should reach the fire area as quickly as possible via land transportation. Optimizing the locations of initial response teams in firefighting, deploying mobile response teams, improving road density, and increasing the speed design of existing roads significantly increases the effectiveness of fire response. Thus, utilizing mobile response teams and increasing the speed design on existing roads can minimize the time it takes for response teams to reach the fire and increase the accessible forest areas within the critical response time (Kasap et al., 2024). In this context, the 23% forest road construction not yet completed in GDF (2022) would be significant in combating forest fires.

Tedim et al. (2018) stated that the faults and deficiencies, such as source deficiency, poor coordination between firefighting crews, errant orders, training deficiencies, non-communication, land management not decreasing fuel consumption, and reneging on safety rules, can turn a forest fire into a LFF. According to FWDs, problems caused by coordination deficiencies (D8) are moderately (5.61) effective in the growth of LFFs. The two groups agreed on this issue, and there was no statistical difference (p=0.724) between them. As forest fires grow, activities such as the number of crews, fire response tactics, equipment organization, logistics activities, and public relations become more complex. Organization and coordination activities, especially in LFFs, involve different categories of people, professionals, or volunteers. Tadesse and Seboko (2013) stated that a clear definition of the responsibilities of the unit tasked with firefighting would increase the effectiveness of the communication and coordination activities. Purnomo et al. (2021) recommended defining the job descriptions of all

institutions involved in combating forest fires to eliminate communication and coordination problems. Bassi and Kettunen (2008) suggested coordinating with stakeholders in combating forest fires, thus pooling existing assets and adopting other measures to reduce the fire risk.

LFFs continue for days without regard for day or night. At such times, personnel work around the clock in the same environment, mostly without shift changes. According to FWDs, problems arising from communication and coordination deficiencies in night work (D9, 5.24) and nighttime displacement and transportation difficulties (D10, 5.26) are moderately experienced in the growth of LFFs. In both issues (D9, D10), the two groups agreed, and there was no statistical difference (p=0.602, p=0.462) between them. On this subject, Hauke et al. (2011) recommended that machines operated at night should have at least one light equipped at the front and rear to ensure safe operation. In addition, Coşgun (2022) suggested that FWDs could use artificial lighting with flashlights or overhead lamps during night work, use glowing clothes, and participate in night work training.

In LFFs, FWDs have duties with irregular schedules outside ordinary hours and involving physical work that lasts 14 days or longer (NWCG, 2022). According to FWDs, there is too much inefficient work (7.16) in the growth of LFFs, owing to fatigue and sleeplessness depending on the prolonged duration of the fire duration (D11). On this issue, the two groups agreed, and there was no significant difference (p=0.144) between them. In the same context, 52% of FWDs agreed that 1–3 days of working time would be suitable during LFFs. These two groups stated that they could work for a maximum of five days. There was no statistically significant difference (p=0.602) between the evaluations of the two groups regarding working time. In this regard, Özer (2022) and Küçükosmanoğlu (1986) stated that the FWDs' sleep and rest needs should be considered and that it would be appropriate to work in shifts.

Fighting forest fires is a dangerous job requiring special equipment and clothing to protect against hazardous environments (Tedim et al., 2020). According to FWDs, the occupational health and safety problem (D12) in the growth of LFFs is below the medium level (4.81). On this issue, the two groups agreed, and there was no statistical difference (p=0.462) between them. In the strategy for fighting forest fires, it is important to determine the principles that all stakeholders must comply with. In this context, as stated in Tadesse and Seboko (2013), all personnel who respond to forest fires should have good fire suppression knowledge, combat the fire with technologically appropriate personal protective equipment, and participate in an organization with a good command structure. All these elements need to be defined in the forest firefighting strategy document.

The lack of training of FWDs (D13) is considered a low-level (3.67) problem in the growth of LFFs. On this issue, the two groups agreed, and there was no significant difference (p=0.823) between them. Budiningsih et al. (2022) emphasize that managing forest fires requires detailed technical, socio-economic, and political intervention. FWDs receive training in fire extinguishing techniques and other technical issues at the beginning of the fire season (Şafak et al., 2023). Avcı and Korkmaz (2021) suggested that firefighting personnel (workers, engineers, and operators) should be well-trained in motivation, determination, willpower, and initiative, as well as in technical training, and this training should be continuous.

Forest firefighting organizations and approaches vary widely from one country to another as a result of many factors, including people and the environment. In the upcoming period, according to many studies (Grünig et al., 2022; Balch et al., 2017; Buckland, 2016; San-Miguel-Ayanz et al., 2013; Taylor et al., 2013), it is estimated that managing LFFs will be increasingly complicated due to climate change, as fire hazard conditions will increase, the fire season will expand, and its severity will increase. In addition, as LFFs become a significant problem in the international arena, the necessity of improving the fire suppression system in fire-affected countries will become more evident and urgent (Tedim et al., 2020). As such, there is a need for research to strengthen international cooperation in fire management and develop a harmonized information system infrastructure at a regional and global level. Particularly, there is a need for research that can produce solutions on how to eliminate "organizational and infrastructure deficiencies".

5. Conclusions

It is expected that forest fires and LFFs will occur more frequently than in the past. The increase in population density affects the rate of fire outbreaks and growth, and the more frequent occurrence of hot and arid years, together with climate change, heighten this danger. In this case, in the fight against forest fires, controllable parameters are as important as factors that cannot be directly controlled. The absence of deficiencies or inadequacies in controllable factors will increase the effectiveness and success of forest firefighting in direct proportion. In the fight against forest fires, the power of the land crews and the infrastructure support (the water resources and number of forest roads) are as important and efficient as the use of technological opportunities (aircraft, fire trucks, and construction machinery). In terms of the forest firefighting infrastructure, it is important to take care of the personnel involved, monitoring their working hours and occupational health, and ensuring safety precautions, communication strategies, and coordination activities are successfully implemented.

As a result of the study, personnel deficiency, construction machinery deficiency, aircraft deficiency, problems based on fire suppression infrastructure (forest road and water resources), non-communication and non-coordination deficiencies, and factors related to occupational health and safety deficiencies were determined to have a moderate effect on the growth of LFFs. The prolonged and continuous work creates a very high level of inefficiency in combating LFFs. In this context, eliminating the shortcomings mentioned in the study will increase the efficiency, success, and motivation of the employees involved in combating LFFs.

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