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Article

Firefighters' Suggestions to Improve Wildfire Management in Portugal

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Abstract: As a follow-up to previously published research, this paper examines the responses of a group (n=185) of professional and volunteer firefighters directly involved in fighting extreme wildfire events of the 2017 summer season in Portugal. The data used in this research stem from two open-ended questions in response to a web-based survey: i) lessons learned and ii) proposals for improving the Civil Protection service. The replies were qualitatively examined. Participants exhibit incomplete awareness of extreme wildfires, and their only answers are i) the improvement of both the current organization and the technical and human resources of the suppression model (question 1), and ii) the increase in human and material resources, the single command, the independence from Civil Protection and the valorization of experience, as the main aspects for the improvement of Civil Protection (question 2). Little attention is given to prevention and to the concept of control capacity, respectively. The answers to both questions showcase scarce knowledge of the paradigm shift in reference to the prevention model. The ratios of missing replies to both questions were 32.43% and 47.57%, respectively. The work stands out for its novelty and originality, as to our knowledge there is a total lack of similar works in all European Union literature.

Keywords: control capacity; extreme wildfire event; EWE; fire management; prevention; suppression model

1. Introduction

1.1. Previous Research on the Topic

A previous paper by the same authors [1] reports the results of a web-based survey conducted among a sample of 185 firefighters (professional and volunteer) that participated in the suppression activities of the extreme wildfires events (EWEs) of the 2017 season in Portugal, i.e., Pedrógão Grande and October 2017 fires. For the first time, this paper provided an essential insight into the experiences, perceptions, and concerns of career (i.e., professional and volunteer) firefighters in Portugal. This topic is indeed almost unexplored in Portugal and in other European Union countries, and is scarcely discussed in general, although it is a vital and crucial point to cope with the new normal of EWEs [2].

For EWEs, a quantitative definition based on the physical characteristics of a fire (e.g., fireline intensity, rate of spread, spotting distance, erratic behavior) was proposed by Tedim et al. [3]. These wildfires exhibit large-scale and complex interactions between fire and atmosphere, generating pyro-convective behavior and coupling processes. This produces an intense, uncertain, erratic, and fast-paced changing fire behavior (fireline intensity > 10,000 kWm^{-1}; rate of spread >50 $mmin^{-1;}$ spotting distance >1 km) exceeding the control capacity, exhibiting prolific massive spotting [3], episodes of explosive expansion, and extreme growth of rate (e.g., values of burnt area in hectares, per hour or

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per day) [4]. Extreme fire behavior, with unpredictability surpassing the expected behavior, overwhelms the decision-making capabilities of any emergency system.

1.2. The Extreme Characteristics of the 2017 Wildfire Season in Portugal

There are no doubts that the Pedrógão Grande and October fires of the 2017 season in Portugal were extreme in terms of wildfire metrics. Pedrógão Grande exhibited one of the most severe fire behaviors on record in Europe, showcasing4 extreme vorticity phenomena and projection of incandescent material both at a short and long distance: in some moments, late in the afternoon, the intensity of Pedrógão Grande fire reached values of 20,000 to 60,000 kWm^{-1} [5] with a rate of spread of 3.9 up to 5.9 kmh^{-1} [5], a peak of 15.2 kmh^{-1} for 10 minutes in the interval 8 pm to 9 pm, an unparalleled value in forest fire literature [5], a spotting activity up to 2.3 km [5] and a plume 13.5 km high. The average rate of spread was 725.8 hah^{-1} [5] but from the 17th to the 18th of June there was an increase in burnt areas larger than 20,000 ha in one day [5].

In the interval between 2:30 pm and 9 pm of June 17th, the burned area exhibited an unexpected increase after 6 pm, when it suddenly jumped from 416 ha, burned in 3½ hours, to 3,799 ha at 8 pm and 8,258 ha at 9 pm, i.e., with a peak of 4,459 ha in the interval 8 pm – 9 pm [5]. Such increment was due to intense spotting activity following a *downburst*, caused by the abrupt collapse of the convection column. This condition, which occurred before the onset of summer, about only six hours after the fire outbreak, and at a time of day when the severity of fire weather conditions is normally expected to attenuate, confirms the unpredictability of EWEs.

Unheard extreme values of intensity were also recorded in the seven complex October 2017 fires in Portugal (100,000 kWm^{-1} estimated in Lousã, [6], with averages of 30,000 - 45,000 kWm^{-1} to 50,000 - 90,000 kWm^{-1} [6] and spotting activity 0.5 to 2 km (ibid.). Rate of spread values of 8.8 kmh^{-1} [6] were estimated in the fire of Vilarinho-Lousã, with average values of the rate of spread of 2,223 hah^{-1}, and 9,138 ha in 2 hours (interval 3 am - 5 am 16th October). For the same fire, a value of >80,000 kWm^{-1} was assessed in the interval 9 pm - 10 pm; the maximum value of plume height, marking the nature of a pyro-convective event, was 9.8 km (15th October).

The replies of firefighters about such events, gathered by the survey, were consistent with the above-mentioned values: most of them reported values of flames height of 15 - 30 meters, and mentioned relevant rate of spread as one the most impressive characteristics (Leone et al., 2023). In the fire of Pedrógão Grande flames 40 m high are reported (Guerreiro et al. 2017). We did not gather data concerning either the rate of spread or the spotting distance, which can be assessed only ex-post and with some difficulty by research teams who are not able to systematically survey each fire for statistical purposes.

1.3. The Objective and Hypothesis of This Research

In order to explore the topic of the perception of extreme wildfires events (EWEs) by volunteer and professional firefighters more in-depth, we decided not to present and discuss the results of replies to the two open-ended questions in the already published paper [1], postponing their analysis to this specifically dedicated paper that integrates and complements the first one. Thus, in this second paper, we check directly through their words, how professional (PF) and volunteer (VF) firefighters perceive events such as extreme wildfires [3]; identify lessons learned in the 2017 fire events and analyze the firefighters' opinions on the improvements they would like to see in wildfire management and training. Our research, although limited to a relatively small sample, can be considered a pioneering milestone and a basis for broader discussion.

Thus, we formulated the following hypothesis of work:

Hypothesis 1. *Both groups of respondents not only recognize the existence of changes and extremeness in fire behavior but also acknowledge the inherent limitations of the suppression model.*

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Hypothesis 2. *The respondents perceive the increase in human and material resources as more significant than profound changes in the organization of wildfire suppression, indicating a preference for strengthening existing capabilities rather than advocating for a paradigm shift.*

2. Materials and Methods

2.1. Data Collection

The general web-based survey was grounded on a questionnaire, with close-ended and two open-ended questions (Leone et al., 2023). The two open-ended questions, discussed in this paper, were:

(i) Considering your personal experience, what are the main lessons you draw from the 2017 fire season?

(ii) In your opinion, after the experience of the 2017 fires, what changes would you like to see implemented in the organization of the Civil Protection system?

The open-ended questions give respondents the opportunity to truly express their opinions [7–10]. Open-ended questions are explanatory in nature and allow the respondent to provide free-form answers; basically, they permit respondents to express their opinions and comments in the form of sentences, lists, and stories, without the constraint of a predefined list of answers for the respondents to choose from.

2.2. Methodology

A preliminary analysis was conducted to better characterize the two sub-samples of respondents, considering that the number of replies to the open-ended questions was less than the total number of respondents. Additionally, the number of replies provided by professional firefighters (PF) and volunteer firefighters (VF) differed in each case. Using the same criteria to depict the initial group [1], we examined: i) age; ii) level of instruction; and iii) date of job start in the firefighting service.

After this phase, aimed to check if differences exist between the subgroups and the original components of the sample (n= 185), we analyzed the replies to the two open-ended questions by grouping the answers into topics, items, and subitems with the NVivo software. For each of the responses, the number of instances was calculated. To easily capture a synthesis of the replies, we used the technique of the word cloud, a user-friendly way of visualizing in a cluster or cloud of words the frequency of appearance of words in a text [11]. To generate the word cloud the word cloud package in R and the RcolorBrewer package for colors were used. In Supplementary material, figures S1, S2, S3, S4, S5, S6, S7, S8 separately report the word cloud and the related bar graphs for questions 1 and 2, split for the two groups of respondents.

3. Results

In view of the multiplicity of topics and related items, the results will be discussed after each individual subject, with the general discussion being postponed to a separate section.

3.1. Characterization of the Sample

The number of respondents to the two open-ended questions is reported in Table 1. The relative percentage of both replies is very close to the percent distribution of the two groups in the original survey (n=185). Many of the respondents in the general survey did not reply to the open-ended question. The rate of non-replies to questions 1 and 2 was 32.43% and 47.57%, respectively. Altogether, 125 PF and VF replied to the first open-ended question (45 and 80 replies, 36.00% and 64.00%, respectively). To the second open-ended question, 97 PF and VF replied (34 and 63, with almost the same percentages 35.05% and 64.95%, respectively).

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Table 1. Number of professional (PF) and volunteer firefighters (VF) having replied to the open-ended questions.

Firefighters	Original Sample		Replies to Question 1		Replies to Question 2	
	Total	%	Total	%	Total	%
Professional	62	33.51	45	36.00	34	35.05
Volunteers	123	66.49	80	64.00	63	64.95
Total	185	100	125	100.00	97	100.00

Some replies were considered invalid, because out of the scope of the survey. In total, the cases of invalid replies and lack of response were 61, that is 38.36% of the valid replies to the first question and 82 to the second question, i.e., 50.93% of the total number of valid replies. The missing replies to the first question, concerning lesson learned, are more numerous by VF (17 for PF vs. 44 for VF, respectively), whereas in the second one, concerning suggestions for improvement, they are more numerous by PF (54 for PF vs. 28 for VF), a difference that will be discussed later. The percentages of missing replies are in line with the current literature on the subject, which reports a generally accepted average of missing replies of 18%, with a range from 3 to 50% vs. 2% of closed end-questions [12]. Missing replies can be due to many factors, including length of interview, lack of time, difficulty, reluctance, lack of propensity to write and concisely express opinions, and level of cognitive burden. These conditions met our expectations, and it is the reason why recall mail was not used to reduce the ratio of missing replies from operational people accustomed to ensuring 24 hours a day of continuous service all year round.

The respondents are fundamentally male (> 84%) and started work as firefighters before 2001 (Table 2). The educational level is satisfactory as >80 % have at least 12 years of education. Master's is the highest level found. The mean age is about 43 years in both questions (1st question - PF- 42 and VF - 44 years, respectively) and 43 years for both groups for the 2nd question.

Table 2. Characteristics of the PF and VF which replied to the two open-ended questions.

Items		Question 1				Question 2			
		PF		VF		PFS		VF	
		No	%	No	%	No	%	No	%
Gender	Male	38	84.4	69	86.25	32	94.1	55	87.3
	Female	7	15.6	11	13.75	2	5.9	7	11.11
	Prefer not to answer	0	0	0	0	0	0	1	1.59
Age	<25	2	4.4	7	8.75	2	5.9	3	4.76
	25-29	4	8.9	5	6.25	1	2.9	5	7.94
	30-34	5	11.1	11	13.75	3	8.8	11	17.46
	35-39	8	17.8	9	11.25	6	17.6	5	7.94
	40-44	10	22.2	12	15	9	26.5	7	11.11
	45-49	5	11.1	16	20	5	14.7	14	22.22
	50-54	4	8.9	14	17.5	3	8.8	12	19.05
	55-59	4	8.9	6	7.5	3	8.8	4	6.35
	60-64	3	6.7	3	3.75	2	5.9	2	3.17

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Education level	2nd cycle (6 years of studies)	1	2.2	3	3.75	1	2.9	1	1.59
	3rd cycle (9 years of studies)	5	11.1	6	7.5	4	11.8	4	6.35
	Secondary school (12 years of studies)	29	64.4	41	51.25	21	61.8	35	55.56
	Bachelor or license	7	15.6	23	28.75	5	14.7	18	28.57
	Master	3	6.7	7	8.75	3	8.8	5	7.94
Job starting date	1973-1990	8	17.8	18	22.5	6	17.6	14	22.22
	1991-2000	17	37.8	23	28.75	15	44.1	19	30.16
	2001 -2010	13	28.9	19	23.75	9	26.5	17	26.98
	2011-2021	7	15.6	19	23.75	4	11.8	12	19.05
	No Response	0	0	1	1.25	0	0	1	1.59

The results of replies to the two open-ended questions are reported in Tables 3 and 4. We observe that the number of replies (instances) does not correspond to the number of respondents, since in most cases their statements contain more than one item, thus being separately considered, and labeled as instances. The more interesting and pertinent replies to both open-ended questions marked by PF or VF, and a #figure, corresponding to the position of the single respondents in the general database, are reported (e.g., VF # 45).

Table 3. Lesson learned: Topics, items, and number of instances.

Topics / Items		PF		VF		Total	
		No	%	No	%	No	%
Fire behavior	Change in the behavior of fires	11	18.03	13	13.26	24	15.09
	Awareness of the 2017 fires repeatability in the future	1	1.64	1	1.02	2	1.26
Fire exceeding control capacity	Impossible to fight certain fires	5	8.2	9	9.18	14	8.81
Material and human resources	More material and human resources	5	8.2	9	9.18	14	8.81
Defense system organization	Governance/Coordination Issues	7	11.48	10	10.20	17	10.69
	Communication in the operational theatre	0	0	4	4.08	4	2.52
Strategies and tactics	Personal and team safety	17	27.87	15	16.32	32	20.13
	Changes in strategies and tactics	5	8.20	2	2.04	7	4.40
	Limitation in the use of water in a direct attack	0	0	1	1.02	1	0.63
Preparation	Firefighters' preparation	1	1.64	7	7.14	8	5.03
	Firefighters' endurance	1	1.64	3	3.06	4	2.52
Proactive initiatives and actions	Prevention	4	6.5	18	18.37	22	13.84
	Surveillance	1	1.64	0	0	1	0.63
	Increasing penalties	1	1.64	0	0	1	0.63
	Spatial planning	3	4.92	6	6.12	9	5.66
Total		61	100	98	100	159	100

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No replies	17	21.79	44	30.99	61	43.57

Table 4. Improvement suggestions: Topics, items, subitems, and instances.

Topics / Items/ Subitems			PF		VF		Total	
			No	%	No	%	No	%
Material and human resources	Equipment and vehicles		4	7,27	6	5,66	10	6,21
	Human resources		7	12,73	10	9,43	17	10,6
	Supporting and investing in firefighters		3	5,45	3	2,83	6	3,73
	Change the financing model		0	0,00	1	0,94	1	0,62
Defense system organization	Governance and coordination issues	Single command to firefighters	12	21,82	17	16	29	18
		Independence from Civil Protection	1	1,82	1	0,94	2	1,24
		Less politicization of the Civil Protection system	1	1,82	2	1,89	3	1,86
		Better organization	2	3,64	3	2,83	5	3,11
		Concentration of combat in a single entity	1	1,82	1	0,94	2	1,24
		Command of operations	0	0,00	1	0,94	1	0,62
		Valorizing experience	0	0,00	1	0,94	1	0,62
		Enhanced power and autonomy to operators in the theater of operations	1	1,82	2	1,89	3	1,86
		Collaboration within institutions	1	1,82	3	2,83	4	2,48
		Less bureaucracy and procedures simplification	0	0,00	2	1,89	2	1,24
	Communication in the operational theatre	More information for operators on the field	0	0,00	1	0,94	1	0,62
		Effective communication system	1	1,82	1	0,94	2	1,24
	Firefighters career and work conditions	Career dignification and remuneration	2	3,64	5	4.71	7	4.34

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		Better working conditions	1	1,82	0	0	1	0,62
Strategies and tactics	Personal and team safety		0	0,00	1	0,94	1	0,62
	Changes in strategies and tactics	Management of aerial means	0	0,00	1	0,94	1	0,62
Preparation	Firefighters' preparation	More and rigorous formation, and updated training models	3	5,45	7	6,6	10	6,21
		Professionalization of firefighters	4	7,27	4	3,77	8	4,97
		Specialization	3	5,45	9	8,49	12	7,45
		Knowledge about fire dynamics	1	1,82	3	2,83	4	2,48
	Citizens 'preparation	Culture of training the population from school age on	2	3,64	3	2,83	5	3,11
Proactive initiatives and actions	Spatial planning of the territory and forests		4	6.5	18	18.37	22	13.84
	Prevention		1	1.64	0	0	1	0.63
Do not know/ Does not fit			1	2	8	7,55	9	5,59
Total			55	100	106	100	161	100

3.2. Firefighters' Lessons Learned from the 2017 Wildfires

From the 125 respondents, 159 statements were identified and organized into 7 topics; each of them in turn divided into one or more items, for a total of 16 (Table 3). The topics here listed are not in decreasing order of instances but rather in terms of logical sequence: Fire behavior (26; 16.35%); Fire exceeding control capacity (14; 8.81%); Material and human resources (13; 8.18%); Defense system organization (21; 13.21%); Strategies and tactics (40; 25.16%); Preparation (12; 7.55%); Proactive initiatives and actions (33; 20.75%). Strategies and tactics are clearly the dominating category, followed by Proactive initiatives and actions both representing 45.91% of the instances.

A point-by-point discussion of results follows, with the transcription of some representative statements by respondents, translated from the original replies in Portuguese.

3.2.1. Fire Behavior

The fire behavior topic is split into two items. Changes in fire behavior, recognized by 24 firefighters (11 PF and 13 VF, respectively), and Awareness of the future repeatability of the 2017 fires, which is mentioned by only 1 PF and 1 VF.

- Changes in fire behavior

Out of the 24 firefighters who mentioned changes in fire behavior, a vivid depiction emerged of the unprecedented extremeness experienced during the 2017 wildfires in Pedrógão Grande and October. These firefighters highlighted the exceptionally high rate of spread and unpredictability, which they had never encountered before in their firefighting careers [1]. The most used terms to express the fire behavior are "(…) very fast, violent, (…) rapid and less predictable" (PF#25), "(…) aggressive" (VF#31), "(…) accompanied by abnormal propagation speed (VF#26) and "(…) enormous proportions in a short period of time" (VF#20).

The sudden changes are attributed to "(…) violent meteorological phenomena" (PF, P139), "(…) atypical and extreme meteorological conditions" (VF, P26), and "climate change" (VF#31; VF#152).

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- Awareness of the 2017 fires repeatability in the future

There appears to be limited awareness regarding the possibility of extreme fire events reoccurring. Only two firefighters consider that EWEs can occur: "(…) in the short term and more intensely" (VF#43), and what happened in 2017 "(…) should it happen again, it could be the same, or worse" (PF#146).

Some concern about preparation is revealed by two firefighters as "(…) the behavior of forest fires is changing and that the need to adapt is not being addressed" (PF#161), and "(…) few things had improved" (PF#146).

3.2.2. Fire Exceeding Control Capacity

- Impossible to fight certain fires

Although 26 firefighters recognize changes in fire behavior, only 14 respondents (5 PF and 9 VF) consider that the 2017 wildfires were "(…) humanly impossible to fight" (VF#163).

Respondents never explicitly mentioned the term control capacity or limit of suppression [13]. Only a scant minority of respondents acknowledge some limit: "(…) twice as many firefighters or crews would have the same result" (VF#48), and "(…) in this type of fire ground fighting is not possible, only protection of populations and settlements" (VF#158)."

3.2.3. Material and Human Resources

- More material and human resources

Insufficient material and human resources are mentioned by 13 respondents, eluding to the lack of effectiveness in fighting the 2017 EWEs: "The fight was not effective with the few resources we had, and we could not involve the entire area due to its size" (VF#142). In addition, the simultaneous fires in October 2017 provoked "(…) the dispersion of means and lack of them (…)" (VF#140).

It was mentioned that "Due to climate change, fires are increasingly aggressive, and we are not prepared for an effective combat with the existing means" (VF#31).

The belief that all fires can be effectively controlled with increased material and human resources reflects a lack of awareness regarding the nature of extreme wildfire events (EWEs) and their operational limitations. In addition to the call for more resources, there is also an advocacy for better remuneration for firefighters.

3.2.4. Defense System Organization

Defense system organization issues are mentioned by 21 respondents (7 PF and 14 VF). This topic is split into two items: Governance/Coordination Issues, and Communication in the operational theatre.

- Governance/Coordination Issues

Governance/Coordination issues were mentioned by 17 firefighters (7 PF; 10 VF). One of the problems identified was the "Need to improve the organization of the combat forces and their coordination "(VF#126). It can be explained by "(…) weaknesses in the command of fires" (VF#155), "Bad coordination in the command post." (VF#53), and by "Command positions, chiefs and ranks of operatives, occupied [by people] with lack of experience, training, and discipline (PF#22).

Respondents also claim an excessive number of entities intervening in the same operation: "The effectiveness of operations may improve (…). If each Civil Protection agent was dedicated only to its main mission everything would go better, and the command and control would be more effective. Too many entities too many commands too much noise (….)" (VF#152).

Some readiness issues were also identified: "The Combat Groups, besides the pre-positioned ones, take a long time to form, dislocate and reach the theater of operations" (PF#22); this negatively influences the initial attack which "(…) should be as committed and muscular as possible, especially in multi-occurrences in the same municipality/district" (PF#22). The availability and the readiness of machinery were mentioned too: "Need for more tracked machines available and with less time for activation" (VF#126).

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Logistical challenges, particularly regarding the availability of food and fuel for vehicles, were also identified as significant issues: "Logistics (food/fuel) very difficult to manage when climbing beyond SGO [sistema de gestão de operações, in Portuguese; Operation management system, in English] Phase III mainly"(PF#22).

- Communication in the operational theatre

Communication issues in the operational theatre, mentioned by only 4 firefighters, highlighted three main aspects. Firstly "(…) many communication failures" (VF#131). Effectively, SIRESP, the Portuguese Integrated System of Emergency and Safety Networks (O Sistema Integrado de Redes de Emergência e Segurança de Portugal, in Portuguese) collapsed in the Pedrógão Grande fire [5]. In the October 2017 fires, the problem recurred: "Frequent complete absence of communications of any kind, at many moments the only possible form of communication was the social networks and other forms of communication through the Internet, namely through mobile phones with which it was impossible to use GSM (Global System for Mobile Communications) services" [6].

Secondly, the experience of communication failures highlights the need for an urgent response to address this issue. Lack of communication is also perceived in terms of personal safety "(…) communication is extremely important in a theatre of operations, without it we feel "lost" and "isolated" (VF#131).

Problems of scarce and difficult interaction within operating forces were finally identified:" Unfortunately, in Portugal, we have several types of forces to fight forest fires and each one of them speaks a different language, has a different level of education, and experience, they can hardly understand each other on the theatre of operations when each agent will act differently" (VF#23).

3.2.5. Strategies and Tactics

The topic Strategies and Tactics was mentioned by 40 respondents and comprises three items. The most representative is Personal and team safety (32 instances; 20.13%), followed by Changes in strategies and tactics (7; 4.40%). Limitation in the use of water was mentioned by only one respondent.

- Personal and team safety

Personal and team safety gathers 32 mentions, i.e., 20.13% of the total. The need for operations based on awareness rather than impulse is clearly emphasized: "We should never forget the safety conditions, and if the fire is not within our reach, we have to admit it and ask for help. We should never act on impulse" (PF#133). Replies focus mainly on the correct use of PPE (Personal Protective Equipment) (e.g., VF 11; PF12) and LACES, the internationally recognized safety protocol (Lookout(s) - Anchor point(s) - Communication(s) - Escape routes - Safety zone(s) [14]. One of the firefighters states that "It is imperative that the entire team is knowledgeable about the LACES protocol. So that safety is always ensured" (VF#33).

Beyond personal safety, the importance of team safety is mentioned (e.g., PF,12; PF,58) and the focus of firefighters is to guarantee the safety of village inhabitants mainly through evacuation (PF,134; VF,136).

Negative comments on the current procedure for the distribution of security equipment are also present "(…) It makes no sense the continuous neglect of personal protective equipment and combat equipment allocated to firefighters" (VF#158).

- Changes in strategies and tactics

Changes in strategies and tactics were mentioned by 7 respondents (5 PF and 2 VF) with a focus on the initial attack, which "(…) must be muscular at all levels, land, and air" (VF#14).

The change in paradigm is implicitly recognized and advocated also: " (…) increasingly we will have fires with extreme behavior and for longer periods, and the necessary evolution passes more by forest management and not so much by the fight" (PF#24).

- Limitation in the use of water in direct attack

The presence of fire events that exceed control capacity, although described but not explicitly acknowledged, is confirmed by a single comment regarding the use of water in a direct attack, which

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remains the primary tool of the current suppression paradigm in many countries, including Portugal: ”(…) the use of water for direct combat is not the most effective way to fight fires of large proportions” (VF#186). The limited efficacy of water use in a direct attack [15,16] does not seem to be widely recognized by the respondents.

3.2.6. Preparation

This topic with 12 instances (i.e., 7.55% of the total) is split into Firefighters’ preparation, with the higher number of instances (8 instances, 1 from PF and 7 from VF) and Firefighters‘ endurance (4 instance, 1 from PF and 3 from VF).

- Firefighters’ preparation

Many respondents acknowledge the lack of preparedness to combat fires of the magnitude experienced in 2017. However, it is important to note that this recognition is not universal among all respondents: “Portugal was not prepared for an event of this size and characteristics” (VF#150). Thus, the focus is shifted to the extreme characteristics of fire and the insufficiency of means: ”Due to climate change, fires are increasingly aggressive and we are not prepared for an effective fight with the existing means (VF#31); a “Lack of response capacity for multiple/large fire scenarios” (VF#36). Three respondents argue there is a lack of preparation with the existing means, but do not realize the limits of control capacity.

Other critical remarks denounce a deficit of experience and training of the teams (e.g., “The big failure for me was the lack of experience of the teams to fight” (VF#147), pointing out that ”Firefighters should be required to meet stricter criteria for education, training, and knowledge. The philosophy of everyone passing is no longer admissible. Just as we cannot all be doctors, we cannot all be firemen” (VF#158).

Professionalism and operational knowledge of the terrain are also under critical scrutiny, highlighting the importance of these factors in effectively responding to wildfires. “It makes no sense that a COS [commander of the relief operation] comes from another municipality and takes a position only by graduation, without knowledge of the territory, and expected behavior of local fires. The surveillance, command, and action should belong to the same structure, in this case, more knowledgeable and more capable firefighters to agglomerate all these activities” (VF#158).

The importance of knowledge is also fully recognized: ”I defend the motto "Saves Who Knows" Only who has the knowledge and capability can save lives and not "Life for Life". In my opinion, the motto "Saves Who Knows" complements the previous one with the knowledge of the cause, because if before acting we know how to recognize all the associated risk factors, the success rate and safety in the operation will be higher” (VF#23).

The respondents' description reflects a sense of anxiety regarding professional growth and advancement in their field: “Each operative must want to evolve physically, psychologically, and with knowledge of the cause. We cannot sit and wait for the System to come to instruct us; we must seek this instruction at a personal/private level” (VF#23).

- Firefighters’ endurance

Four comments were considered (1 from PF and 3 from VF) that refer to moods or emotive reactions, expressed with rhetorical accents: “Volunteer firefighters never give up fighting a fire of these dimensions, even with the difficulties caused by smoke, flame spread, and heat” (VF#162) “. We are so big and at the same time so small” (VF#178); “I take it that our strength compared to the strength of Nature is nothing” (PF#170).

3.2.7. Proactive Initiatives and Actions

The proposed solutions to combat EWEs appear to be controversial yet balanced. While a considerable number of respondents advocated for reinforcing suppression efforts, a group of 33 firefighters, predominantly volunteers, recognized the significance of proactive initiatives and actions aimed at preventing fire outbreaks, reflecting a diversity of perspectives and approaches.

- Prevention

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The "(…) need to invest more in prevention" (VF#180; VF#17) is recognized and is mainly identified in terms of fuel management initiatives: "Invest more in fuel management" (VF#18). Prevention was advocated by 22 respondents as "Prevention is the best fight" (VF#13) and should be done "(…) throughout the year (…)" (VF#148). There is a "Lack of cleanliness, near the industrial zones and the houses, villages, cities" (PF#39), and in addition " (…) the incompleteness of the work of land cleaning" (….).

The aspiration to expand fuel management efforts beyond the Wildland Urban Interface is advocated, with the need for better intervention of the "(…) authorities to supervise the cleaning of land within the perimeters of the villages" (VF#2).

Respondents emphasized that fuel management should encompass the cleaning of forests as well. They recognized that this approach not only influences fire behavior but also contributes to the safety of firefighters. As one respondent pointed out "More security. And the main thing is prevention through forest clearing" (PF#58).

The need to create "(…) more accesses" (PF#135) also mentioned, as it helps in organizing and deploying suppression activities during fires, but inevitably leads to a higher number of individuals entering and traversing forests. Unfortunately, not all individuals exert prudence or caution when navigating these areas, potentially leading to risky situations. In addition, when more access is possible, it is also necessary to restrict or deny it, should wildfire risk reach critical levels [17].

Other suggested prevention measures include "(…) containment strips as well as water supply points" (VF#P6). The initiative of containment strips reiterates the traditional creation of fire breaks or fuel breaks, currently considered less efficient in comparison with areal interventions [18].

Both groups mention generic "cleaning" operations of forest and urban areas, but without a clear awareness of their meaning, implementation, and expected efficacy. Such replies seem more an expression of common sense than professional knowledge of the problem of extreme fires.

For more effective prevention strategies, solutions are also sought in better equipment and higher remuneration to foster motivation.

- Surveillance

Only one respondent mentioned that one of the problems is the "(…) lack of control and surveillance" (PF#139).

- Increasing penalties

Penalties are mentioned just once as a measure of containment of fire ignitions: " (…) exemplary penalties on the people who caused these fires instead of considering them always as crazy people" (PF#127.)

Law enforcement plays a vital role in fire prevention efforts, aimed at the prevention of fire outbreaks or minimizing fire severity and spread. Penalties serve as a crucial element in this strategy, designed to act as a deterrent [19,20], but their implementation faces challenges, particularly in cases of voluntary fires where identifying clear criminal perpetrators is rare.

3.2.8. Word Cloud

In this section, we report the graphs and the statistics of the word cloud. The most frequently used words are fire, safety, preparation, lack, and firefighting (Fig. 1). The high representativeness of the terms fire, combat, and firefighting shows the importance given to suppression. In addition, there is attention paid to the safety and preparation of the firefighters' teams. Of notable interest is the representativeness of the word lack, expressing organizational and managerial shortcomings whereas the word need arguably refers to resource paucity and insufficient training among others.

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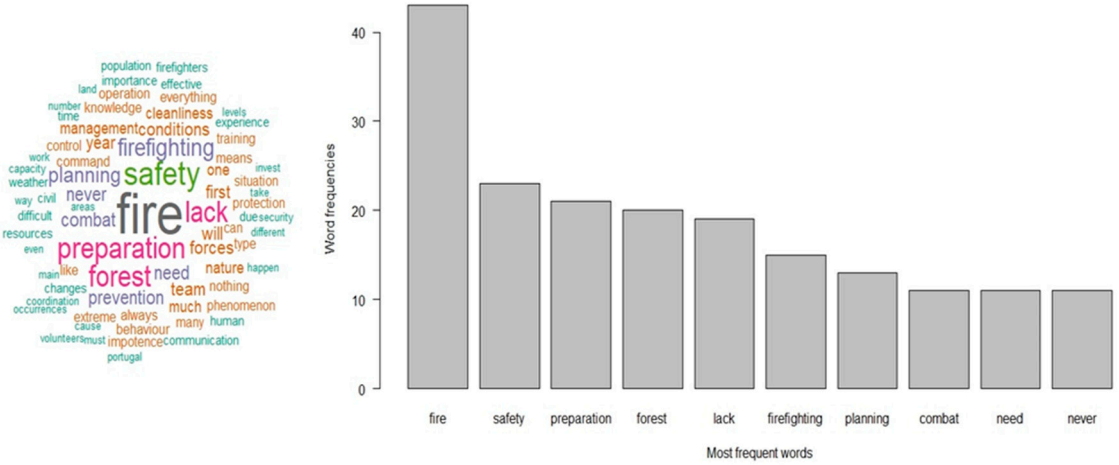

Figure 1. Lessons learned: Word frequency analysis with the word cloud method and bar graph.

3.3. Improvement Suggestions

Table 4 reports the 161 replies (55 PF, and 106 VF, 34.16 % and 65.84% respectively) to the second question, which are summarized in 5 topics, 13 items, and 23 sub-items. 82 firefighters did not respond, of which 54 PF and 28 VF, 50.47% and 20.74 %, respectively. The topic with the highest number of instances is Defense System Organization (63 instances, 23 from PF and 40 from VF). The two following topics are Preparation (39 instances, 13 from PF and 26 from VF), and Material and human resources (34 instances, 14 from PF and 20 from VF). The other two topics, Proactive initiatives and actions, and Strategies and tactics, have lower representation. The multiplicity of instances with low numerical value suggests a general lack of overview of the problem, which is fragmented into many individuals with highly heterogeneous answers.

A point-by-point discussion of topics and items follows, accompanied by the statements of selected respondents. It is notable that in some instances, the responses appear almost identical, suggesting that the respondents may have discussed and shared their perspectives within the same team or group.

3.3.1. Defense System Organization

This topic encompasses three main items (i.e. Governance and coordination issues, communication in the operational theatre, and firefighters' career and work conditions) with a plethora of sub-items, most of them with a very low number of mentions.

- Governance and coordination issues

In this item, 10 sub-items were considered (Table 4). The respondents made several suggestions to improve the current system. The first group of opinions is related to the relationship between the firefighters and Civil Protection Authority (ANEPC, in Portuguese). A single command is the most scored sub-item (with 29 instances) throughout the entirety of question 2. Unification of command for the fire brigades appears to be the most felt and inescapable need by both PF and VF (12 and 17 instances, 21.82 % and 16.04% respectively). A "(...) single command in the Voluntary Fire Brigade. There should also be a single organized command within the fire fighters' structure with greater rigor, discipline, and knowledge" (PF#139). The ANEPC structure is autonomous and independent of the government and the Unification of command is motivated by different reasons including:

(i) political protection of the category, for instance: "If things continue this way no one will defend us or represent us, and [give] more support for firemen; we are running short of men, we are tired of being treated badly by the government, especially by the Prime Minister" (VF#125)

(ii) control and command chain: "Single command of all forces in order to streamline the command process and simplify the deployment of air assets." (VF#186). "The surveillance and

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command and action should belong to the same structure, in this case, firefighters more knowledgeable and better able to agglomerate all these activities" (VF#158). This is related to the opinion of two respondents advocating independence from Civil Protection, suggesting a "(…) national and district command of firefighters and not being associated with Civil Protection" (VF#19) and thus proposing: "In my opinion, there will be much to change, however in my understanding we should start by separating what should never have been united (because it was the most economical solution at the time), the Fire Brigade is a Civil Protection Agent like all the others and we are not Civil Protection, end with the slogan "we are the backbone of the Civil Protection" - only when it suits someone" (PF#24).

It is noteworthy that in April 2023, the Portuguese Firemen's League (Liga Portuguesa dos Bombeiros) established the National Operational Command of Firemen. This creation, as reported in the provided source (https://lbp.pt/comando-nacional-de-bombeiros-esta-completo), was implemented independently of the existing Civil Protection legislation. The establishment of this command aligns with the expressed desires of the respondents, further indicating the relevance and recognition of their perspectives.

One of the arguments that supports this opinion is brought forth by three respondents who call for less politicization of the Civil Protection system, accusing ANEPC (Autoridade Nacional de Emergência e Proteção Civil in Portuguese; National Authority for Emergency and Civil Protection in English) of being highly politicized and influenced by ruling parties. It is suggested that "(…) the command positions of the ANEPC structure should no longer be influenced by the governing political party" (PF#127).

The second group of replies is related to a transversal need to simplify and make more efficient the complex and cumbersome system of defense against rural fires, firstly by reducing the number of entities involved in it, which can include more than 50 bodies [21]. One proposal included "Restructuring the firefighting system, reducing the number of intervening entities and investing in the structures that have always existed for this purpose, professionalizing and giving the proper conditions for the performance of the mission" (PF#134). Thus, an organization passes through the rearranging of the components in a single national service, with the aim of producing a less complex and more harmonized system, without overlapping the functions of different forces. "The entire Civil Protection structure should undergo a more effective reorganization and legislate for all fire services to have equal means and equipment, all modern and effective" (VF#179).

In this process, the concept of territorial zones, with respective commands, reappears: "Fire brigades with their own command and activation of the old operational areas with their respective commands" (VF#183).

Unification and harmonization of language and procedures are also felt as a pressing need, together with valorizing the experience of commanders on the ground and introducing knowledge tests for career access, as: "(…) we will all have to speak the same language, because the Civil Protection System cannot be led by elements without knowledge of cause; a wildfire theatre of operations has nothing to do with a military theatre of operations, nor with the political environment, why do we continue to appoint elements with military careers and political party connections to these positions? Why is it that to firemen, the most numerous forces in the national territory, the specialization training is provided for free to the Special Civil Protection Force and not to the Volunteer Firemen? Why is it that the entrance to a Permanent Intervention Team is only through physical tests, with no knowledge tests? If we implement these changes, I think we are on the right track" (VF#23).

As for the command of operations, there is a need to trust a person with experience on the ground rather than rankings, well knowledgeable of both the territory and of the activity of firefighting on the ground. Three respondents asked for enhancing the autonomy of expert operators in the theatre of operations because they "(…) know the terrain" (VF#160).

Experience of commanders is also under scrutiny: "Many changes must be implemented, from the training of an element that moves to the active corps, to the Command of Operations. Sometimes

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commanders have never experienced a wildfire and come with the command of a reinforcement group" (PF#168).

To enhance the effectiveness of the system, some respondents propose that surveillance, command, and action should belong to the same structure; in this case, firefighters would be more knowledgeable and better able to agglomerate these activities. There should be a single organized command within the firefighters' structure, with greater rigor, discipline, and knowledge. In addition, ANEPC "(…) should be more attentive to the lived experience" (PF#127).

The third group of suggestions is related to the collaboration within institutions (4 instances) and the necessity to lower bureaucratic hurdles and simplify procedures (2 instances). Replies underline the necessity of consultation, interaction, and collaboration at different scales and levels, including population. The responses mentioned the need for "Greater consultation with the operatives, as part of the solution" (VF#50), "(...) real collaboration between the different means of Civil Protection" (VF#36).

Engaging in consultations can effectively mitigate overlapping of activities and conflicts arising from a lack of competence, which can lead to unproductive episodes of miscoordination and even defiant attitudes, such as non-compliance with instructions from the official chain of command and control. By fostering a culture of consultation, organizations can promote effective communication, collaboration, and alignment, ultimately enhancing coordination and minimizing potential conflicts.

One of the respondents offers a detailed complaint of such situations: "In my opinion, the different agents should dedicate themselves only to do what they were created to do: it is not normal in an operative theatre, not getting elements of GNR (Guarda National Republicana; National Guard in English) to control access to the accident area, or to create evacuation corridors, and in the same place have members of this force trying to do the work of firefighters completely uncoordinated and without accepting the orders from the PCO (Posto de Comando Operacional, Operational Command Post), it is a question of doing more and more effectively" (VF#172).

- Communication in the operational theatre

Communication issues are mentioned only by 3 respondents who identify the need for more communication by field operators and an overall more effective communication system: "An effective and safe communication system, safety and operational conditions for the operatives involved in the operational theatres" (VF#20).

- Firefighters' career and work conditions

In this item two main aspects were highlighted: Career dignification and remuneration were mentioned by 7 firefighters, and Better working conditions were identified by 1 PF. Advocating for decent career prospects and improving working conditions are essential, as they contribute to creating a motivated team. It is understood that better remuneration " (…) and an adequate specific career" (VF#81), play a significant role in boosting motivation levels "(…) since firefighters provide a public service of great complexity. If they are more and better remunerated it could be possible to demand them to do more and better" (VF#81).

Four VF mentioned the following key factors as crucial to addressing in the discussion on career dignification and remuneration: Better working conditions, Improved career prospects, Enhanced remuneration, and a Heightened sense of dignity and moral recognition for individuals engaged in the risky task of saving lives, protecting assets, and rescuing people. This is particularly significant for volunteer firefighters who represent a cost-effective yet undervalued resource. Supporting and investing in firefighters is a reinforcing step: "Ensure that volunteer firefighters are paid more at the time of the forest fire fighting with DECIF, (Dispositivo Especial de Combate a Incêndios Florestais in Portugais; Special Device for Fighting Forest Fires in English)" (VF#162).

There is a strong advocacy for the establishment of decent careers for firefighters, achieved through investments in a unified firefighting force. The emphasis is on providing better working conditions, professional development opportunities, and improved remuneration to attract and retain highly skilled firefighters " (…) instead of creating structures on top of structures that, by themselves and without the support of the Firefighters, solve nothing (where they exist, because in the overwhelming majority of municipalities they do not even exist)" (PF#139).

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Better working conditions are related to the need for better equipment and increased remuneration: ”Fundamentally, the prevention mechanisms must be better equipped and properly remunerated so that the elements can be motivated and available. It is also important to guarantee human and physical means in a credible and realistic way. Not only guaranteed on paper” (VF#148).

To further enhance the discussion, it is imperative to conduct a thorough review of working conditions. Specifically, implementing short-term working rotations for front-line personnel and establishing different specialties based on a gradient of risk levels. These measures aim to ensure optimal operational efficiency and safety. By implementing short-term rotations and aligning specialties with varying risk levels, the objective is to promote a well-balanced and secure working environment, as firefighters call for “(…_) better conditions for all voluntary firemen who have their own jobs and who, despite all the legislation produced so far, continue to be undermined” (VF#5).

3.3.2. Preparation

In the topic of preparation, there are two main items: Firefighters’ preparation mentioned by 34 firefighters (11 PF and 23 VF) and Citizens’ preparation mentioned by 5 respondents (2 PF and 3 VF).

- Firefighters’ preparation

Four sub-items were considered namely Specialization (12 instances which 12 from VF), More and rigorous formation and updated training models (10 instances, of which 7 from VF), Professionalization of firefighters (8 instances, 4 from PF and 4 from VF), and Knowledge about fire dynamics (4 instances of which 3 from VF).

Special attention is given to specialization in various tasks and activities. For instance, “Rotation in the work periods of all combatants. The mission of the combatants of the initial and extended attack should not be the same as that of the ones who do the aftermath and surveillance. There should be teams specialized in aftermath and surveillance, freeing up combat operatives for other interventions and thus recovering their capacity” (PF#153). In addition, it was suggested that firefighters’ headquarters should have the support of health professionals. Respondents noted that “Using health professionals in the fire service can help the population and would provide great improvements in the firefighting force” (VF#51). For instance, in case of evacuation, accidents, or fatalities, the presence of psychological support experts would be essential in diminishing posttraumatic stress.

There is a recognition of the need to professionalize firefighters. Some respondents suggest achieving a certain level of professionalization among firefighters ("Sufficient professional firefighters in each volunteer firefighters’ associations" - VF#64), while also acknowledging the importance of maintaining volunteer participation. A respondent provided the following comment: “In general, volunteer firefighters should evolve into professionals. In addition to the ECIN's ((ECIN-Equipa de Combate a Incêndios, in Portuguese; Firefighting team in English), the associations should have teams (EIP- Equipas de Intervenção Permanente in Portuguese, Permanent Intervention Teams) working 24h, preferably more than one team and complemented in the same with the association's employees and giving continuity to the volunteering maintaining those same teams of volunteers. We are approaching the subject in relation to the rescue of the Portuguese population and I still don't understand how this rescue continues to be assured mainly by voluntary elements, since there are still corporations that don't have enough teams to maintain the rescue without recourse to volunteers. I'm not saying that we should put an end to volunteering, but that we should change the percentage between professional and voluntary elements. A higher percentage of professionals and a lower percentage of volunteers. Volunteering is always important and an added value for everyone” (VF#142). “The professionalization of firefighters with a more balanced remuneration of the operatives (risk allowance) is the key for a job with more responsibility and commitment, also allowing for a more adequate response from the operatives. “(VF#81). Demand for professionalization in the sector, with a greater presence of professional firefighters and fewer volunteers, was expressed as a clear and urgent requirement. It is deemed “unacceptable that the safety and rescue of the Portuguese population largely depend on voluntary contributions” (VF#142).

However, some respondents strongly recommended complete professionalization to effectively address the current challenges. They emphasized the need for a Civil Protection system primarily

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composed of professional personnel, highlighting the limitations of the current reliance on volunteers and inexpensive labor. Professionalization is seen as "(…) the key to the continuity of a work with more responsibility and commitment. because you can demand more appropriate response from the operatives. and consequently, starts to exist a more balanced level of remuneration of operatives" (VF#,81).

Considering that wildfire are increasingly complex socio-ecological phenomena, provide firefighters with more scientific knowledge on fire dynamics, including extreme wildfires, is of paramount importance. A respondent claim for "(…) more dynamic information, awareness and education on risk" (VF#31).

To form a firefighting force highly skilled it is crucial to go beyond the mandatory investments in material and human resources. Formation, and training, are deemed essential steps in firefighting. It is crucial to move away from a philosophy where everyone is expected to be proficient in all aspects.

- Citizens' preparation

It was also suggested by 1PF and 2 VF, to establish and spread a culture of training within the population, starting from an early age: "(…) working in depth on prevention, focusing on a culture of training in the population from school age onward" (PF#79). It is considered a highly efficient and impactful approach to promote and develop not only prevention but preparedness measures, as well.

3.3.3. Material and Human Resources

This topic revolved around four key elements: Human resources (17 instances), Equipment and vehicles (10 instances), Support and investment in firefighters (6 instances), and Change in the financing model (mentioned once). The frequency of these mentions reflects the significance attributed to the suppression paradigm. Strengthening this paradigm is a necessary and logical step, enabling a more effective response to Extreme Weather Events (EWEs), which have been devastating the country with unprecedented violence. The responses, categorized according to these elements, provide valuable insights and illumination on the topic.

- Human Resources

For 17 respondents increase the human resources is a pressing concern, without providing additional explanations. It likely stems from a decline in staffing levels over the past decade, which has reached approximately 33% [22]. Factors contributing to this reduction include an aging workforce, depopulation, and a lack of interest among younger generations who are not drawn to the demanding working conditions and limited benefits associated with volunteer firefighting, including low remuneration.

- Supporting and investing in firefighters

Some respondents highlight the need for increased investment in the firefighting workforce, as it is seen as a resource that is, "(…) practically free for the state" (VF#158).

- Equipment and vehicles

More equipment and vehicles are considered crucial to strengthening operational capacities and for ensuring equitable treatment in comparison to other emergency response forces. "The entire Civil Protection structure should undergo a more effective reorganization and legislate for all fire brigades to be equipped with the same modern and effective means and equipment" (VF#179) and to obtain "(…) at least equal treatment with other forces" (VF#48). Beyond vehicles, the respondents mentioned the need for increased investment in PPE (Personal Protective Equipment), and "(…) more computer equipment (tablets) and training in this area for all firefighters and not just commanders" (PF#39).

- Change the financing model

One of the respondents suggests changing the financing model (PF#184) but does not provide specific suggestions on how to implement this change.

3.3.4. Proactive Initiatives and Actions

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In this topic two items were recognized: Spatial planning of the territory and forests (5 instances, all from VF) and Prevention (9 instances, 4 from PF and 5 from VF).

- Spatial planning of the territory and forests

Some replies on the topic of territory and forest planning exhibit a tendency towards oversimplification, as they lack depth and fail to address the complexities involved. Respondents mentioned “Investing more in advance land-use planning” (VF#41) and that “There should be more supervision in the cleaning of bushes and around dwellings” (VF#159). Once again, there is a tendency to offer simplistic and inadequately analyzed suggestions, such as the idea of keeping the forest and surrounding areas "clean," as if it alone could effectively mitigate the threat of extreme events. The complexities associated with reducing the hazardous accumulation of fuels are not adequately addressed or acknowledged in these responses [23].

- Prevention

The replies demonstrate a lack of knowledge about prevention strategies and the necessary resources for building a robust Civil Protection service capable of addressing the growing threat of extreme fires. There is a need for more comprehensive information and allocation of resources to prioritize prevention measures.

Surprisingly, prevention efforts, particularly those aimed at proactively avoiding catastrophic events that exceed the suppression threshold, appear to be lacking in the responses. Prevention is often portrayed merely as a suggestion to maintain “clean” forest and surroundings, which reflects a limited understanding of the concepts of fire-smart communities and territories [24–26]. This observation raises concerns about the level of knowledge and awareness regarding comprehensive prevention strategies within the firefighting community, despite statements such as “Give preference to the prevention of fires and not to fighting”(PF#170) and “(…) empowering Civil Protection agents according to risk analysis. Urgent to work on the organization of the territory. More means of prevention” (VF#43). It is essential to recognize the multifaceted nature of fuel management and develop comprehensive strategies that consider the ecological, social, and economic aspects of wildfire prevention and mitigation.

3.3.5. Strategies and Tactics

- Personal, teams’, and citizens’ safety

Safety is predominantly viewed in terms of equipment, rather than individual awareness of safety behavior. It is notable that this perspective received a surprisingly low number of responses, indicating a potential gap in addressing the importance of personal safety awareness and behavior. “It makes no sense the continuous neglect of personal protective equipment and combat equipment allocated to firefighters” (VF#158).

Furthermore, there is a concerning lack of depth when addressing the critical issue of evacuating people. The responses often overlook the complexity, social costs, and challenges associated with relocating a population or specific groups from their habitual living areas. Evacuations entail significant challenges, such as dealing with resistance, potential conflicts, and the psychological stress experienced by wildfire victims. Failing to acknowledge these complexities can undermine the effectiveness of evacuation plans and strategies. It is crucial to approach the topic of evacuation with the necessary depth and understanding to ensure the safety and well-being of affected populations [27–29], contrary to what was stated by a respondent : “I don't think that the Civil Protection system needs many changes, but I would propose a faster and more efficient way of safely removing civilians from villages” (VF#136).

- Changes in strategies and tactics

Aerial resources were only mentioned by two respondents: “The management of the aerial means should be totally military with own means, e.g., air force” (VF#P8). In Portugal, the firefighting system prioritizes firefighters as the primary backbone, considering their crucial role in combating fires, and ensuring public safety, while aircraft and vehicles play supportive roles [22].

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3.3.6. Word Clouds

Here following we present the graphs depicting the word cloud and the frequency of the most used words, namely Command, Fire, Firefighters, and Brigade (Fig. 2). The significant representation of these terms highlights the importance placed on fire suppression. Moreover, attention is given to the protection and training of firefighting teams. The use of the term "better," although not contextualized, suggests a broader need for improvements across various domains and at a large scale. It indicates a demand for enhancements and advancements in different areas related to firefighting and fire management.

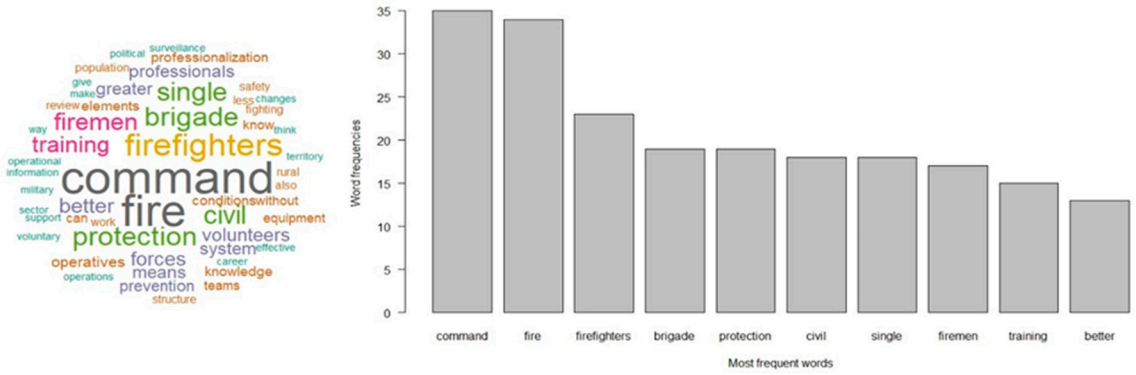

Figure 2. Improvement suggestions. Word frequency analysis with the word cloud method and bar graph.

4. Overall Discussion

This second paper gives voice to firefighters directly involved in the operational activities of the dramatic 2017 wildfire season in Portugal. It examines how both PF and VF really perceive EWEs. It aims to identify the lessons learned from the 2017 wildfire season and explore their recommendations for enhancing the wildfire management system. We assert that the opinions and suggestions of firefighters can provide valuable insights to improve the adaptation to the current "new normal" conditions. By considering these voices and perspectives, it becomes possible to enhance the firefighting and management strategies, aligning them with the evolving challenges posed by these extreme events.

4.1. Lessons Learned from the Experience

It is concerning that most of firefighters do not fully perceive the distinct nature of the new types of events represented by EWEs. Only a small minority of respondents acknowledged that the 2017 wildfires were not normal fires and that similar events may occur in the future even with unprecedent intensities and rate of spread. Currently, firefighters are still adhering to procedures and methods of intervention that are limited in their capacity to effectively control wildfires beyond a certain threshold [15,30].The concept of the limit of control seems not widely known or understood by firefighters, despite many respondents recognizing that the 2017 wildfires were the most severe they had ever faced [1]. Metrics that are essential for assessing fire behavior, such as intensity, rate of spread, and spotting were never mentioned by the respondents.

When comparing the percentages of responses by PF and VF in each topic, it is observed that the situation is similar between the two groups. The main difference between the two groups lies in preparedness and prevention, where a higher percentage of replies from volunteers is observed. Both recognized the changes and extremeness in fire behavior; however, they may not fully acknowledge the limitations of the traditional suppression model and the need for a paradigm shift. Both groups remain strongly attached to the suppression model, which may hinder their ability to effectively respond to the increasing number of EWEs. The firefighters' response requires a more comprehensive and adaptive approach that encompasses prevention, preparedness, and resilience-building

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measures. Encouraging a shift in mindset and fostering a culture of flexibility and innovation can help equip firefighters to tackle the challenges posed by these evolving fire conditions.

As a result, the lack of awareness can lead to the belief that command and coordination issues, as well as insufficient resources, are the main reasons for the lack of success in managing EWEs. The response put forth by the respondents, though not offering a comprehensive solution [25,31], emphasizes the importance of reinforcing human and material resources while prioritizing security measures. In addition, respondents emphasize the need for improving suppression management, addressing governance and coordination issues, and investing in robust communication systems.

Replies clearly support the reiteration of the current suppression paradigm which is based on protocols and inspired by the doctrine of hitting fire fast and hard [32], focusing on a strong and immediate response. This response, which overlooks the intensity of fires, is plainly ineffective in dealing with EWEs like those experienced in 2017 [3], Moreover, it is entirely inadequate for upcoming seasons, as current fire suppression capabilities are projected to gradually fall short [33,34].

As for VF, we observe that the volunteer brigades provide service to various communities, with special emphasis being placed on isolated settlements. The fact that over 90% of the services provided by these corporations are in the social areas, including health [5], may contribute to the increased interest and curiosity in a wide range of topics. VF are maybe more impressed by the perception of sudden changes in fire behavior. This could be attributed to their diverse experiences and exposure to different situations while serving the community in various capacities.

The practical implications of these results highlight the need to: i) enhance the awareness regarding the physical nature of fires and the concept and characteristics of EWEs. Although the presence of professional fire analysts in suppression teams will become a necessity soon, we propose that (ii) all firefighters should possess the basic skills to analyze fire behavior in operational settings. As the characteristics of fires vary along a gradient, it is crucial for firefighters to adapt their attack tactics accordingly and in safety. Understanding the different categories of fires and the limitations they impose on suppression activities is essential. Additionally, (iii) collecting on-the-ground data of fire behavior should be prioritized.

4.2. Improvement Suggestions

The replies to the second question are indeed unique and thought-provoking, further reinforcing the observations made in the previous section. Suggestions illustrate an evolved version of the traditional suppression paradigm, centered around the availability of a core standby system that can swiftly and aggressively respond to fires as soon as they occur. Despite the limited number of responses, the participants touch upon various aspects of the classical organizational structure that has been widely employed for fire control purposes for many years. The responses provided do not explicitly mention the advocated shift in the firefighting paradigm that is supported by a growing number of researchers (e.g.,[24,25,35–40]); by international institutions [17,41], by Scientist Advisory Groups [42]; by worldwide financial groups [43]; by cultural organizations [44], and by mass-media. New paradigm in fire management is grounded on the concept of coexistence with fire. It emphasizes allocating a significant portion, at least 60%, of the firefighting budget to prevention efforts. This involves redistributing financial resources to prioritize prevention measures, rather than solely focusing on suppression. Additionally, the new paradigm recognizes, accepts, and utilizes the beneficial aspects of fire as a management tool, including employing tactics such as prescribed fire, backfire, tactical fire, and suppression fire in a strategic and controlled manner [26,45,46]. The concepts of resistance, resilience, and vulnerability must also be incorporated into fire management strategies. The paradigm shift gives special emphasis to prevention, which must complement rather than eliminate the suppression paradigm, enhancing and strengthening its operational capacities. It aims to prevent the occurrence of events that exceed the capacity for control and enhance the suppression capability for the numerous fires of lesser significance [44]. The main activities regarding prevention are [47,48]: i) building strategic prevention infrastructure; ii) initiatives in preventive sylviculture and wide-scale, non-linear fuel load reduction to mitigate the risk of severe wildfires [18,49]; iii) recovery of traditional fire knowledge (TFK); iv) the involvement and empowerment of

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local fire risk prone populations through their education, information, and training; v) emphasizing resistance and resilience; and v) reducing the vulnerability of homes and infrastructure (e.g. Firewise Communities).

Respondents are indeed very prodigal in details but exhibit no interest in a new approach. Despite acknowledging the unprecedented behavior and impacts of 2017 fires, respondents exhibit a lack of awareness or skepticism regarding their complexity, and impossibility to be suppressed. It is notable that the term extreme wildfire event does not appear in the responses, which is peculiar considering the context. Moreover, there is a striking absence of the terms control capacity or suppression limit in all replies, indicating a failure to recognize the diminishing effectiveness of the traditional suppression model.

The replies of PF and VF indicate a reluctance to abandon the long-held belief in the supremacy of the suppression paradigm. Both groups appear tied to fire as an "enemy", to be faced by "hitting it hard and fast" [32,50,51], i.e., to the legacy of fire exclusion[46,49,52]. This approach, widely disseminated by the prominent European Forestry Schools and Academies in the 19th century, aimed to prevent and suppress fires at all costs [53]. It is true that PF have been traditionally trained and ingrained in the suppression model, which prioritizes a rapid and aggressive response. Their solution to the problem of wildfires often revolves around improving the current organization, whereas a more effective approach entails a shift towards prevention strategies alongside the rapid response and aggressive suppression techniques that PF are trained for. This is emphasized by bombastic and rhetorical expressions, such as "muscled attack" [51], "a fast and blunt attack" [50,54,55]. The general reluctance, not only in Portugal, to accept the paradigm shift is confirmed by the reluctance to acceptance of certain practices, such as prescribed burning. Both PF and VF often struggle to acknowledge and accept the idea that fire, traditionally seen as their "enemy," can be utilized as an effective auxiliary tool in combating wildfires. Prescribed burning, despite being supported by national and regional laws in some countries, continues to face suspicion and, in some cases, open opposition, such as in Italy. This resistance towards prescribed burning as a tool of land management persists despite its legitimacy and the presence of other accepted forms of fire use, such as suppression fire, technical fire, and backfire [45,46,49].

It is indeed important to acknowledge that Extreme Weather Events (EWEs) surpass the control capacity or suppression limit, which is typically defined as 10,000 kWm^{-1} [13,16]. Recent literature, such as [16], reports the possibility of extreme fire intensities reaching up to 150,000 kWm^{-1}. The current control capacity operates at a mere 6.67% of its maximum theoretical value, [56]. In Portugal, the control capacity operates at only 10% of the intensity observed during the Lousã fire in October 2017, which was estimated to be around 100,000 kWm^{-1} [6]. The prevalence and acceptance of the suppression model can be attributed to several factors [38,57–60]: i) Aggressive firefighting is an obvious response to avoid or mitigate damages; ii) The sense of control over a chaotic and unpredictable natural event; iii) The impressive nature of fire suppression operations (e.g., water bombing) connected with the heroism involved, and the sense of strength when the objectives are attained; iv) Successful fire suppression efforts yield immediate and tangible results, which are readily apparent to politicians, the public, and decision-makers; v) Discounting bias, status quo bias, and aversion bias; vi) Knowledge gaps around wildfire behavior and related uncertainty; vii) Institutional barriers and self-reinforcing mechanisms that contribute to policy failure; and viii) Vested interests and resistance to changes among the different agencies involved in providing services and technological products also play a significant role in perpetuating the dominance of the suppression model.

The wildfire suppression model serves important needs and is generally effective in managing most of wildfire events that fall within the threshold of control capacity. It remains a realistic and practical option, for firefighting operations and is likely to continue being utilized in the future, despite contrasting opinions, well summarized by the notion that "The old way of fighting fires by sending firefighters – that's gone" (Castellnou M., mentioned by [61]).

Recalling the second hypothesis, it can be concluded that the perceived need for increasing human and material resources, modifying firefighting command modes, unifying firefighting forces,

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and implementing smaller management changes takes precedence over the advocated deep changes in the organization of wildfire suppression. The urgency and relevance of these immediate measures are emphasized, while the paradigm shift towards prevention is seen as a gradual and less immediate priority. Indeed, it is evident that prevention is not emphasized as the most relevant aspect by the two groups. It appears to have a marginal presence and is notably absent in the most prioritized topic. The focus of attention seems to be more directed towards immediate responses: resource allocation, command structure, and other operational considerations. It is not surprising that there is a total lack of comments to fire causes in the responses. Without a thorough understanding of the factors that contribute to fire ignition and spread, it becomes challenging to implement targeted prevention strategies.

The results of the word cloud analysis confirm the marginal consideration of fire causes in the responses, as documented by the following Table 5: prevention along with planning, ranks only in the 7th position in question 1 (VF reply), and in 10th position in question 2 (PF reply). Notably, it does not appear within the first 10 most frequent replies in the aggregate word clouds for both questions. The most frequent words, i.e. the first three positions in the two aggregate groups (PF+VF), clearly recall the suppression model, namely fire, command; safety; preparation, and firefighting.

Table 5. The ten words identified by the word cloud in order of decreasing frequency in questions 1 and 2, respectively all respondents aggregated, only PF and only VF.

Rank	Question 1			Question 2		
	PF +VF	PF	VF	PF +VF	PF	VF
1	Fire	Fire	Fire	Command	Command	Fire
2	Safety	Forest	Forest	Fire	Fire	Command
3	Preparation	Lack	Preparation	Firefighting	Brigades	Professional
4	Forest	Necessary	Lack	Brigades	Civil Protection	Firefighters
5	Lack	Preparation	Combat	Protection	Firefighters	Volunteers
6	Firefighting	Behaviour	Fight	Civil Protection	Single	Firemen
7	Planning	Planning	Prevention	Single	Firefight	Operations
8	Combat	Safety	Safety	Firemen	Professionals	Knowledge
9	Need	Security	Forces	Training	Training	Better
10	Never	Training	Team	Better	Prevention	Civil Protection

The practical implications of the results highlight the need for a comprehensive and inclusive discussion among firefighters and the ANEPC to address the following issues: i) identify and solve the latent conflict between Civil Protection and firefighters, as indicated by the numerous instances related to the need for a unified command independent from Civil Protection; ii) reduce or avoid the high politicization of Civil Protection to ensure that decisions and actions are driven by expertise and effectiveness rather than political considerations; iii) improve the recruitment system, training programs and the allocation of command assignment; iv) valorize the experience, knowledge, and competences of expert firefighters; v) adopt a more rigorous evaluation process in the pre-career selection of firefighters; and vi) create greater awareness of the importance of prevention as the preferred solution for addressing wildfires issues. Addressing these implications requires collaborative efforts, open dialogue, and the active involvement of firefighters and ANEPC representatives. By addressing these key areas, it is possible to improve the effectiveness, efficiency, and overall approach to firefighting and wildfire management.

5. Conclusions

Our research, albeit conducted with a limited number of respondents, provided valid qualitative insights rather than statistical data. By utilizing open-ended questions, we were able to delve into the

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respondents' mental models, problem-solving strategies, hopes, fears, and other aspects that contribute to a deeper understanding of their perspectives [62]. From the replies provided by field operators, it appears that the proposed change in Portugal following the unprecedented and infamous 2017 wildfires season is primarily focused on enhancing the existing suppression system. This includes improving the system through the allocation of more resources, both in terms of equipment and human personnel, as well as implementing changes in command structures, organizational practices, and the expertise of commanders. Field operators' replies reveal dissatisfaction, concerns about efficiency, and a strong desire for simplified procedures and the unification of different functions (surveillance, command, and action).

The multiplicity of issues raised by the respondents underscores the need for a comprehensive discussion among institutions, stakeholders, and operators on the ground. The problem of the new normal represented by EWEs is too serious and complex to be tackled by a firefighting service organization still based on the old paradigm of suppression and its ensuing operational limits, which cannot be changed through substantial structural and personnel improvements. The exclusive emphasis on improving suppression capacity is a dangerous underestimation of the challenges posed by EWEs that can exceed control capabilities even at maximum capacity. It also translates into a dangerous diffusion of a misguided message of false security to the communities at risk, who are confident that the current defense system can intervene effectively and promptly without any limitations. Relying solely on the improvement of the current defense system is an inherently flawed approach, as it only addresses the consequences of the problem and neglects the underlying causes.

A more comprehensive and proactive strategy that encompasses prevention measures is essential for long-term success in wildfire management. The occurrence of EWEs is expected to increase due to the influence of climate change, meaning that larger and more severe events could become the "new normal." Consequently, the current fire suppression capabilities will gradually become insufficient in the coming decades. The alarming incoming scenario of extreme events, unprecedented but not unexpected, should represent a stimulus to turn wildfire risk management into an opportunity for the sustainable and inclusive growth of marginal territories [48] by acting on the key driving factors of extreme wildfire occurrence. Implementing Fire Smart Territories represents a promising solution to mitigate the occurrence of extreme wildfires, as this approach focuses on comprehensive interventions at the territory level, addressing both the human and physical components [47]. It involves integrated initiatives of prevention that align with the paradigm shift called for by various stakeholders. By adopting Fire Smart principles and practices, such as fuel management, community preparedness, and land-use planning, territories can better resist and respond to wildfires. This holistic approach emphasizes the importance of proactive prevention measures to minimize the risks associated with wildfires.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org, Figure S1: title; Table S1: title; Video S1: title

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