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Concept Paper

Defining Extreme Wildfire Events: Difficulties, Challenges, and Impacts

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Abstract: Every year worldwide some extraordinary wildfires occur, overwhelming suppression capabilities, causing substantial damages, and often resulting in fatalities. Given their increasing frequency, there is a debate about how to address these wildfires with significant social impacts, but there is no agreement upon terminology to describe them. The concept of extreme wildfire event (EWE) has emerged to bring some coherence on this kind of events. It is increasingly used, often as a synonym of other terms related to wildfires of high intensity and size, but its definition remains elusive. The goal of this paper is to go beyond drawing on distinct disciplinary perspectives to develop a holistic view of EWE as a social-ecological phenomenon. Based on literature review and using a transdisciplinary approach, this paper proposes a definition of EWE as a process and an outcome. Considering the lack of a consistent “scale of gravity” to leverage extreme wildfire events such as in natural hazards (e.g., tornados, hurricanes and earthquakes) we present a proposal of wildfire classification with seven categories based on measurable fire spread and behavior parameters and suppression difficulty. The categories 5 to 7 are labeled as EWE.

Keywords: control capacity; disaster; extreme wildfire event (EWE); large fire; megafire; social-ecological; transdisciplinary

1. Introduction

1.1. Extraordinary Wildfire Events

Most of the two million wildfire events [1] registered every year worldwide are small in terms of burnt area. However, some become very large incidents that have significant ecological and socio-economic impacts. Examples of the latter include events in China 1987; Portugal 2003 and 2005; Greece, Italy, and the US 2007; Australia 2009; the US 2013; Canada and Chile 2016; and Portugal and the US 2017. These extraordinary wildfires tend to overwhelm suppression capabilities, cause substantial damages, and often result in civilian and firefighter fatalities [1–5]. A significant, recent example is the Pedrógão Grande catastrophic wildfire which occurred in June 2017, in Portugal, with 65 fatalities, more than 200 injured people, and 458 structures completely destroyed from which 41 were first residences and 50 secondary homes [6,7]. This extraordinary event burned 45,328 ha [6], with fireline intensities (FLI) from 20,000 to 60,000 kWm^{-1} and a rate of spread (ROS) of 65 m/min [7]. Its extreme behavior and impacts resulted from the complex interplay among macro processes (e.g., atmosphere and fire interaction) and local processes and conditions (e.g., poor initial attack, inadequate risk perception, very strong and variable winds, rough topography, low fuel moisture content, fuel load, fuel continuity, landscape connectivity, poor preparedness, and vulnerable communities).

Some argue that such extraordinary wildfires can be seen as the "new normal" since they are increasing in frequency, magnitude and geographic range [8,9] creating a disproportionate impact on the environment and on communities and effecting an array of societal, economic and political concerns [10–12]. As discussion has grown around how to respond to these fires, so too has the array of terms used to describe such events. However, no agreement upon terminology and methodology to describe such occurrences has arisen and a clear and commonly accepted definition remains elusive [13]. Some authors use terms reflecting narrow disciplinary approaches that fail to capture the diverse and multifaceted complexity and characteristics of such events; some authors adopt a term without defining it; and some define a term by using too specific geographic quantitative metrics. Despite the different terminology used, the authors are referring to the same type of event. This lack of consistency in terminology and conceptualization creates problems in several areas including difficulties with comparing findings and coordinating research, and communication barriers between operational agencies, policy-makers, and the research community. Developing a clear definition based on non-ambiguous language and objective measurable parameters for these extraordinary wildfire events is needed to build a more robust foundation for research, policy, and operational efforts to identify the most effective approaches and strategies (whether prevention, mitigation, or suppression) to reduce the risk from such outlier fires. The perceived nature of the problem and the precision of its definition can influence the level of decisions and the solutions to be considered [14–16]. In an era in which climate change processes are likely to favor the incidence of these extraordinary fires, it becomes even more important to develop a comprehensive definition that follows a transdisciplinary approach.

1.2. The Purpose of the Paper

In the long list of terms used, we believe that *extreme wildfire event* (hereafter EWE), can best capture the complexity and diversity of the phenomenon, the uncertainty of behavior, and relevant physical, ecological, and social dimensions of extraordinary wildfires. As there is a need to address "how fire really exists, not how select sciences can handle it" ([17]; p. 271), this paper proposes a definition of EWE as a process and an outcome.

This paper will first present a review of the terms used to label extraordinary wildfires and a detailed analysis and discussion of the existing terminology. It then proceeds to explain why EWE is proposed as the best term to designate those events. Next, as extreme is a rather frequent term in scientific literature and operational manuals, the advantages and disadvantages of its use are also explored and we develop a definition of EWE, accompanied by a proposal of a quantitative classification. Finally, we discuss the need to distinguish extreme wildfire event as a physical process from a wildfire disaster, which is defined by socio-economic impacts.

1.3. The Originality and Value of the Paper

Although historically wildfire research "orbited around a physical paradigm of fire" ([17]; p. 271), the originality of this paper lies with its seeking to develop a transdisciplinary analysis of EWE as a complex phenomenon which arises from the interplay between natural and social conditions, processes and factors in all the wildfire temporal phases (i.e., prevention and mitigation, ignition, spread, suppression, impacts, recovery and restoration), as illustrated in Figure 1. It highlights the presence of social aspects in all the phases, even in those that are traditionally considered as merely biophysical ones.

This paper captures the nature of EWE in different cultural and environmental contexts, involving diverse areas of expertise (geography, forestry, engineering, psychology, anthropology, fire sciences, remote sensing, spatial planning, and emergency management), and experience in fire research and firefighting in different parts of the world. The goal is to go beyond drawing on diverse disciplinary perspectives to develop a holistic view [18], ensuring that social and behavioral science perspectives are integrated with those from biophysical sciences (e.g., ecology, forestry, meteorology, climatology), and also involving non-scientific actors. An important outcome of this approach is the appreciation of the collective influence of diverse perspectives in all aspects of fire management.

2. Terminological Review of Extraordinary Wildfires

The plethora of terms used to label extraordinary wildfires made necessary a detailed examination of how they have been used and defined, and the strengths and weaknesses of each one. Terms were identified through the knowledge/expertise of the authors and grouped in four categories: (i) *large*, *very large*, and *extremely large fire*; (ii) *megafires*; (iii) *extreme wildfire event*; and (iv) *others*, composed of a number of disparate terms. An extensive review of the available literature was thus conducted, using as pre-identified keywords such categories. The review considered peer-reviewed, editorial-reviewed literature and permitted to identify a number of publications where the fire categories are described also in terms of measurable variables. Publications that use one of the terms only once and without any clarification of its meaning were excluded from the analysis.

2.1. Large, Very Large and Extremely Large Fires

The terms *large wildfire* (e.g., [19–21]), *very large wildfire* (e.g., [21–23]) or *extremely large fire* (e.g., [24]) tend to focus on fire size, although the threshold used by the different authors are rarely congruent; for instance, one paper defines *extremely large fires* (ELFs) using a threshold which is smaller than the one adopted for *very large fires* (VLFs) in another paper.

The size threshold definitions for *large fires* (LFs) are subjective and geographically dependent. Some authors prefer to use relative burnt area (BA) thresholds [25–28] but most of the definitions are based on absolute quantitative thresholds which can change in the course of time, as well as with the geographic area of reference [28,29]. In Europe, thresholds for LFs that have been proposed range from $\geq$ 100 ha (e.g., [30–37]) to $\geq$ 1000 ha [38]. In other regions in the world, the threshold ranges from the minimum values of $\geq$ 20 ha in Arizona (U.S.) [39], to 1000 ha in Australia [40], to 4950 ha in Boreal Shield ecozone of Ontario [41] and to 40,000 ha in the Western United States [42]. The highest thresholds found for a LF were for Eastern Australia with > 41,020 ha [29], for North Australia with > 100,000 ha [43]; for Australia values of 10^6 ha were considered by Gill and Allan [27].

The size threshold for classifying fires as VLFs is similarly variable from > 1000 ha [44] to > 20,234 ha [23], or ranging from 500 ha to 20,000 ha [45,46].

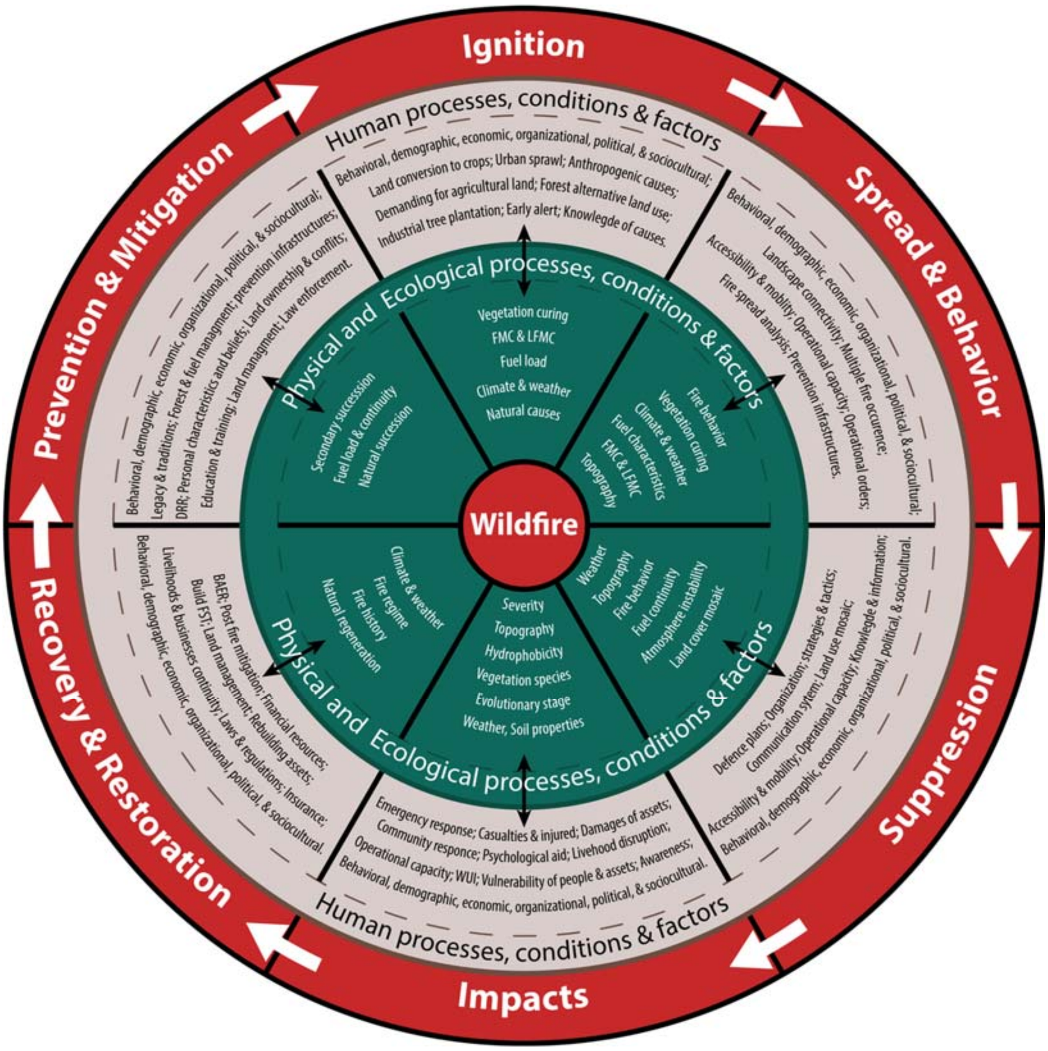

Figure 1. Demonstration of how ecological and social processes, conditions, and factors interplay throughout the wildfire temporal phases. A more detailed list of processes, conditions and factors is reported in Table A1.

Extremely Large Fire (ELF) is not a common term. Fernandes et al. [24] consider a minimum threshold of 2500 ha, equivalent to the 99.9th percentile of fire size in Portugal, to be an ELF. Meyn et al. [47] prefer the term *large infrequent fires* to label the events that are exceptional in their large spatial size, if compared with the fires that usually affect the ecosystems. Schmoldt et al. [48] use the term *extensive fire* to describe very large wildfires, without reference to specific fire features.

Less frequent definitions use as criterion fire behavior (related to intensity, ROS, and long-distance spotting, which can lead to accelerated fire growth) and its relationship with the complexity of operations and the capacity of suppression [19,21,49].

A final classification approach is based on the stages and complexity of suppression operations [50,51]. Here, both LFs and VLFs require the management and oversight of an organized Incident Management Team (IMT); VLFs are extremely difficult to suppress and would be very likely to do extensive damage to any assets they impact [21].

2.2. Megafires

The term *megafire* originally appeared to describe the outbreak of large fires in the Western US [17,52–54] and, by extension, in other regions of the world [38,55,56]. *Megafires* has been used to describe fires in forested ecosystems, rangelands [4] and in the wildland or rural urban interface [57] and are commonly understood to be explosive [53], very large, intense, and uncontrollable fires [23].

Megafire, along with the less common terms *megablaze* [58] and *megaburning* [17], tends to focus on fire size [59] but, in every country the perception of *megafires* reflects local conditions. So far, a commonly accepted threshold of size for *megafires* has not yet been defined, but some values have been proposed. In the US, the National Interagency Fire Center proposes 100,000 acres (40,469 ha) of BA (http://wildfiretoday.com/tag/megafire/), which is the same value for LF by the same organization (https://www.nifc.gov/fireInfo/fireInfo_statistics.html), which may lead to confusion. The EU MEGAFIREs project (ENV4960256, funded under FP4-ENV 2C) proposed a threshold of 500 ha [60] which corresponds to the official limit of LF adopted in Spain [37] and by EFFIS, the European Forest Fire Information System. In Italy, the same value is also proposed [34]. Therefore, it is evident that the fire size threshold to define *megafire* is very different around the world.

Williams and Hyde [4] and a number of other authors argue that the amount of BA alone does not qualify a wildfire as a *megafire*, and thus other fire behavior characteristics are required. For instance, the Italian wildfires in summer 2017 were relatively small in size (not exceeding 5000 ha), but because they lasted for more than 10 days instead of being put out quickly, they were perceived by the public and firefighting organizations as *megafires*. Adams [61] proposes the double criterion of size ($>10^5$ ha) and high intensity, without mentioning any intensity threshold. Other authors do not mention size and instead characterize *megafires* in relation to big intensity, big impacts, and big relief efforts [62].

From the perspective of wildfire control, a megafire is beyond suppression capabilities and efforts, and defeats protection objectives until a major change in weather or fuels occurs [4,5,63].

From the perspective of consequences, *megafires* transform ecosystems and habitats, have relevant long-lasting social and economic impacts to human society (e.g., loss of livelihood, break-up of communities, loss of amenity and aesthetic value), and have high suppression costs, making them a disaster rather than a larger incident [5,53,64,65]. *Megafires* have local impacts but can create cascading regional, or even global environmental and human consequences [5].

The disagreement over the parameters used to define *megafire* makes this term a problematic one. The criteria used to classify *megafires* are similar to the ones used for the LF group, for example, fire size, behavior, its relationship with operational complexity, and the difficulty of suppression. Thus, *megafires*, LF, VLFs and ELFs can overlap in their meaning, creating potential for confusion in events description and operational use. The only criterion distinguishing *megafire* from the others is its impacts (social, economic, and environmental).

2.3. Extreme Wildfire Events

The terms *extreme wildfire events* (EWEs), *extreme wildfire*, *extreme bushfire event*, *extreme fire event*, and *extreme fire* are gaining popularity. However, they are not present in FireWords Glossary [66] and other advanced glossaries and their meaning remains ambiguous, hindering clear definition. Sometimes the terms are used without any explanation [67].

In some papers a range of metrics have been used to define extreme wildfire events (EWE) [1,20,21,54,56,68,69]. None of the metrics are present in more than one paper, with the exception of fire size and windy weather (Table 1). The threshold proposed by Oliveri et al. [69] for Alpine Europe is quite low (BA $\geq$ 105 ha). Lannom et al. [56] propose the adoption of 90th, 95th and 99th percentile of the burned area as the threshold for an EWE. This procedure is not related to a specific value but to a relative context and thus could be accepted worldwide. The majority of authors recognize the complexity of the phenomena and use more than one descriptor to characterize an EWE [1,20,21,54,56].

Some approaches consider EWEs either as individual fires or the coalescence of several fires [1,56], a concept similar to *firestorm* referred to below. Most of the metrics that have been used to classify a wildfire event as extreme are related to fire behavior and fire environment. McRae [20] recalls fire-atmosphere interactions, and associates extreme fires with a higher level of energy, chaos, and nonlinearity. Bowman et al. [1] adopt fire radiative power. In both situations, the metrics refer to the "during the fire" phase [70]. Other approaches are more focused on EWE as an outcome, classified by its size [69] or impact [1,13,56].

Yet again we find no agreement on the definition of EWE, as the authors do not agree on either the descriptors or their use in absolute or relative terms.

Table 1. Comparative analysis of EWE definition criteria.

Definition Criteria	Metrics	Bowman et al. (2017) [1]	Lannom et al. (2014) [56]	McRae (2010) [20]	McRae and Sharples (2011) [21]	Oliveri et al. (2012) [69]	Sampson et al. (2000) [54]	Weber and Dold (2006) [68]
Post-Fire Metric	Size		+			+	+	
	Duration		+					
Impacts	Proportion of area burnt with high severity		+					
	Impacts	+						
Fire Environment	Fuel load and structure						+	
	Wind speed				+		+	
	Wind direction change				+			
	Atmospheric instability *			+				+
	Distance to the wildland–urban interface		+					
Fire Behavior	Extreme phenomena **			+	+			
	Fire radiative power	+						
	Rapid evolution			+				

Note: * As described by the Haines Index; ** Including eruptive fire behavior, vorticity-driven lateral spread, mass spotting.

2.4. Other Terms

In this section, the terms were organized in two groups, respectively considering: (i) exceptional fire behavior characteristics such as flares, rapid increase in ROS, anomalous behavior of flames, spotting; and (ii) the consequences of these events.

In the first group terms related with fire behavior characteristics were gathered. A *blow-up fire* [71,72], is characterized by a sudden change of spread and energy release rates [73]. It has been described as a "rapid transition from a surface fire exhibiting relatively low intensity, to a fire burning in the whole vegetation complex, surface to canopy, and demonstrating dramatically larger flame heights, higher energy release rates, and faster rates of spread" ([74]; p. 67). The *Generalized Blaze Flash* (GBF), i.e., the instantaneous ignition of a forest area in the whole vegetation, from surface to canopy [75], is categorized as a *blow-up fire*.

Eruptive fire defines a condition of extreme acceleration of a *blow-up fire* [28,73] in a limited space and time. In these cases, nearly exponential accelerations may be observed [20,76,77]. Due to their extremely high ROS and intensity, *eruptive fires* can overwhelm any suppression capacity.

The term *conflagration* [78], has been used since 1625, mainly for urban fires, as "a raging and destructive fire" ([79]; p. 3) which causes substantial loss of life and property. It can be "any large fire with storm characteristics" ([72]; p. 4) or a fast and large fire exhibiting many of the features associated with extreme fire behavior (EFB) [80]. McRae and Sharples [2] associate *conflagrations* with violent pyroconvective events in the atmosphere, that produce fire thunderstorms or pyrocumulonimbus (pyroCb).

The terms *firestorm*, *mass fires* or *area fires* have been used for situations occurring when wide areas with high fuel load are burning simultaneously [81]. A *firestorm* is formed by the coalescence of different individual fires [78,82]. Multiple ignitions caused by lightning or spotting may induce *mass fires*, which release large amounts of energy [28].

In the second group we considered terms that emphasize the consequences of events more than their size, and behavior. This group includes: *catastrophic fires* [12,83–86]; *disasters* [1,12,86–89], *disaster-fire* [28], *disastrous fires* [90], *socially disastrous fires* or *social disaster* [91]; and, *socially and ecologically 'disastrous'* [92]. Frequently, these terms are used without defining them, implicitly considering that the meaning is well known and accepted. Some authors consider just environmental consequences [85] and ecosystem degradation (e.g., irreversible soil losses, losses of dominant or keystone species, loss of biodiversity) [87,88] while others focus on impacts to social systems [86,91]. A few papers focus on the consequences of high-intensity fire behavior both on environmental impacts and on deleterious effects to life and assets [12,84,92]. This second group of terms is the only one that focuses primarily on social factors in their definition.

Overall the terms described in this Section 2.4 use criteria similar to those for defining LF and megafires (erratic fire behavior, difficulty of suppression, severity, and social and economic impacts), so making it hard to distinguish between them.

2.5. Why Select the Term Extreme Wildfire Event?

In examining the list of terms, we argue that *extreme wildfire event* best captures the nature of outlier wildfires. In part, we argue that, the adjective *extreme* is most suitable because it describes a threshold situation near the upper ends of the range of observed and expected reality, and also the production of high impacts [93].

The adjective *extreme* is commonly used in wildfire sciences and management communities to point out, among others, fire danger, fire risk, fire behavior, fire regime, and severity. In Table A2, a non-exhaustive list of examples is reported. For each term a definition (or a description, if the former is missing) and its purpose are given.

While some definitions of *extreme* are predictive, others refer to a post fire condition, and none of them is inclusive of conditions during and after the event. They are also specific to the particular disciplinary perspectives or organization cultures.

In essence, *extreme* refers to the top value of a range of categories, and in most cases, it represents values at the extreme tail of a right skewed distribution. When unrelated to a scale of values of a variable, *extreme* is commonly used as an accretive to emphasize the deviance from the normal range of variability of a phenomenon (e.g., extreme fire phenomena, extreme fire landscape). The term *extreme* more accurately represents a deviance from the normal and the upper end of a distribution.

3. Conceptualization of Extreme Wildfire Event

3.1. The Constraints of Fire Size

Geographical or cultural criteria should be avoided to establish a definition of EWE that can be used worldwide. Thus, we do not propose wildfire size as a criterion to define EWE for several reasons: (i) it is place-dependent, reflecting landscape characteristics, so it is not possible to establish a commonly accepted and absolute threshold, that accommodates the variety of situations; (ii) size and severity do not have a direct correlation, because the latter depends on the landscape characteristics and fire behavior; (iii) size tells us little about losses and damages which depend on the affected area characteristics, on fire magnitude, and, mainly, on the vulnerability of the exposed population and assets; and (iv) size can also be the result of wildland fire use, which is an accepted fire management practice in areas where naturally caused wildfires are not a threat to assets, homes or people. The definition should be a statement that attributes a distinctive identity and precise meaning to avoid confusion.

3.2. Extreme Wildfire Event as a Process and an Outcome

A standard definition of EWE should not be just focused on categorizing a fire after its occurrence but should be used to anticipate and provide information to better cope with it, emphasizing the importance of forecasting, preventing, and mitigating. Labeling a wildfire event as extreme, using its post fire characteristics, limits its use to research and ex post reconstruction of events, but gives no contribution to operational activities. For this, the definition must also contain the criteria to distinguish and identify the event as extreme as early as possible after its inception, and during the active phase.

3.3. The Definition of Extreme Wildfire Event as a Process and an Outcome

Wildfires are not all the same, and their threat to environment and society increases with the growing magnitude of the physical process that hinders fire control and makes it difficult or impossible, increasing the likelihood of adverse social and environmental impacts. Although consideration of social implications and outcomes of an EWE are a key reason for the need for a consistent definition, there are similar challenges to that of fire size in incorporating social items directly into the definition as social causes and outcomes are too context dependent. Our definition therefore focuses on physical factors of fire behavior that influence capacity to control given that: (i) the greatest likelihood of adverse social impacts is when response abilities are overwhelmed; (ii) suppression abilities are a social variable that can, to a large degree, be assessed consistently across context; and (iii) the physical dynamics that influence fire behavior are the same around the world. (Table 2).

Fire behavior characteristics with potential to have major impacts on people and assets are fireline intensity (FLI), ROS, spotting, and the sudden change of fire behavior. FLI is the pivotal fire behavior parameter as it determines the capacity of control; it can be evaluated from measurements or observations of ROS and fuel consumption [94] or alternatively can be estimated with an acceptable degree of precision from flame length (FL) [95]. FLI can be also approached through the Fire Radiative Power (FRP), although the associated uncertainty is quite high [96]. FLI estimates from FRP can be obtained for ongoing monitored wildfires by remote sensing imagery. Advantages of FRP include: (i) global, daily FRP observations dating to 2001 (MODIS sensor), which could be used to establish an EWE baseline; (ii) FRP is strongly correlated with FLI [96,97] and radiative FLI derived from MODIS thermal data; and (iii) methods for using FRP to quantify intensity differences between fires/regions have been successfully prototyped [98]. A classification system based on FRP observations is far from perfect, but could improve the classification of EWE at the global scale. The values of FLI can be rather deceptive when applied to different fuel types as their structures imply differences in the relationship between flaming front characteristics and FLI [99,100].

A high intensity fire, occurring in heavy fuel and characterized by long and deep flames, generates heat, moisture, gases and particles, under the form of a plume with an upward movement. Smoke, toxic fumes and haze create poor visibility and, consequently hinder evacuation and the use of firefighting aircraft. They are also responsible for short and long-term health problems (e.g., [101–103]) and even loss of lives which can occur not only during but also in the aftermath of an event. The upward convective motion of the plume is powered by the amount of energy released by the combustion, integrated by the latent heat released when vapor condensation occurs [104–107]. The convective activity contributes to changes in the wind speed and wind direction in the immediate vicinity of the fire, caused by the modifications of local winds and creation of inflow into the fire. In addition, it injects steam, smoke, combustion gases and combustion particles into the stratosphere, and launches firebrands into the atmosphere [108], so significantly contributing to extensive spotting. If the amount of energy is enough, the buoyancy of the plume permits its upward convection to the vapor condensation level, with the development of cumuliform cloud tops. In particular conditions of air instability, cloud tops have the shape of pyrocumulus (pyroCu), fire-aided or caused convective clouds, which are rather common, and not a cause of concern [109]. Very rarely pyroCu can evolve to pyroCb [110,111] characterized by considerable vertical development, able to reach heights up to 14 km [6,112] and generating precipitation, downdrafts, and lightning. PyroCu and pyroCb affect smoke lofting and transport [109]. When the vertical upward motion ceases, convective updrafts can reverse and become downdrafts, which hit the ground and spread out, in all directions, so inducing changeable wind direction, and becoming responsible for the strong fire-induced winds often observed at the fire front which may drive erratic fire spread [110], with implications for firefighters' safety. Rarely, a pyroCb produces downbursts, which are gusty, erratic and intense winds causing unpredictable changes in FLI, FL, ROS, direction of fire spread, and ember spotting [113].

Table 2. Criteria for the definition of EWE and their social implications and outcomes.

Criteria	Indicators		Social Implications and Outcomes
Fire behavior	FLI	≥10,000 kWm^{-1}	**DURING FIRE SPREAD AND SUPPRESSION** **Increase of the area of intervention:** (i) Requires more fire suppression resources; (ii) Increases the threatened area and potential losses and damages. **Response capacity of suppression crews:** (i) Reorganization of suppression activities is made difficult by the increasing ROS; (ii) Deployed crews are rapidly overwhelmed. **Capacity of reaction of people and displacement capacity** is overwhelmed by ROS and massive spotting. **Impacts:** (i) Smoke problems: increased hospital admissions during and immediately after the fires; poor visibility; impacts on displacement and on the use of firefighting aircraft; (ii) Loss of lives. **AFTER SUPPRESSION** **Short -term and long-term impacts:** (i) Loss of lives and injured people; (ii) Economic damages; (iii) High severity.
	Plume dominated event with EFB	Possible pyroCb with downdrafts	
	FL	≥ 10 m	
	ROS	≥ 50 m/min	
	Spotting	Activity Distance	
	Fire behavior sudden changes	Unpredictable variations of fire intensity Erratic ROS direction Spotting	
Capacity of control	Difficulty of control	Fire behavior overwhelms capacity of control Fire spreads unchecked, as suppression operations are either not attempted or ineffective	**DURING SUPPRESSION** **Immediate consequences:** (i) Entrapments and fire overruns; (ii) Unplanned last moment evacuations; (iii) Entrapments with multiple fatalities and near misses; (iv) Fatal fire overruns.

Note: The criteria to define EWE are only contained in the first and second column. The integration in the table of social implications and outcomes (fourth column) has the purpose to show the interplay of fire behavior and capacity of control with several social issues. The implications and outcomes are not exhaustively listed and they are not exclusive and specific for EWEs but certainly they can be magnified in case of EWEs occurrence.

ROS is very dependent on the type of fuel, topography, and weather conditions (especially wind velocity) and influences the fire perimeter extent. An increasing perimeter length requires more human and technological resources to control the fire and can affect the response capacity of suppression crews, which can be rapidly overwhelmed [114]. ROS can reach values of about 333 m/min [115] or even 450 m/min [116] and is considered extreme when it is ≥ 50 m/min [117]. ROS can also have major impacts on the safety of the evacuation process.

Spotting refers to the ignition of new fires, due to downwind ignition of brands, firebrands of bark, or larger embers launched from a primary fire [108,118]. It is strongly dependent on the convective column (induced by fire intensity), and on wind velocity and direction. Short-range spotting can reach up to several tens of meters, intermediate-range spotting can reach up to a few kilometers, while long-range spotting can reach distances of tens of kilometers ahead of the main fire [119]. Spotting distances of up to 25 km from the primary fire were recorded in 1983 in Australia [108] reaching a maximum recorded distance of 33 km in the 2009 Black Saturday bushfires in Victoria (Australia) [84]. Massive spotting activity increases the ROS and thus the area of intervention, requiring more fire suppression resources. It makes fire breaching possible across an extended obstacle to local spread. Massive spotting and high ROS overwhelm displacement capacity. Spotting-dominated cases increase the threatened area and potential losses and damages. [108]. Multiple ignitions from spotting can overwhelm firefighting resources [49] and increase the risk of entrapment for both firefighters and residents (learningcenter.firewise.org/Firefighter-Safety/1-11.php). Control tactics and strategies to anticipate fire behavior, instead of simply following the flames, that might work on large fires (e.g., pre-existing fuel breaks, use of extended attack resources, burning out) are impeded by long-distance spotting, severe turbulence and extremely high ROS [4].

Sudden changes of fire behavior consist of unpredictable variations of fire intensity, erratic ROS and direction, spotting, and occurrence of fire-caused winds. Sudden changes of fire behavior are a significant safety danger to firefighters [120,121] and to population and assets, and can overwhelm suppression efforts.

Another criterion to define EWE is the capacity of control. It is strongly dependent on fire behavior and on place-based technological knowledge and limits (e.g., [19]), particularly the capacity to identify potential spread and intensity of wildfires, and the ability to develop both tactics and strategies (implying identification of objectives and priorities in firefighting, and consequently, tactics and maneuvers). This is more an expression of local levels of organization, resources, and training for firefighters. In the current technological conditions, the accepted limit of capacity to control a fire is 10,000 kWm^{-1} [122–126]. Beyond 10,000 kWm^{-1}, it is well accepted that even heavy water bombers are ineffective [127], and fire control is not possible with current day technology and technical resources [128]. Long flames also make fires increasingly difficult to control and represent a threat for firefighters who must operate approaching to fire front, but respecting their "safety zone" [74]. With an increasing FLI, the quantity of water to be eventually used as an extinguishing agent to contain flames grows. When FLI is close to the 10,000 kWm^{-1} threshold, the water amount needed to contain flames is evaluated in 25 to 30 liters every 30 seconds per meter of front [129].

It is important to distinguish cases where it is realistically impossible to cope with a fire, from those where control can theoretically be achieved but lack of needed resources inhibits the ability to do so. In these cases, rather than recognizing the shortfall of the system, the failure of suppression activities may be, inappropriately, justified by labeling them as extreme fires. Such arguments are problematic as they can hide wildfire management weaknesses and failures, thereby decreasing the likelihood of addressing the issue. Failure to suppress a fire due to inadequacy of local fighting crews or lack of training can produce a disaster, even with fires that are not necessarily extreme, such as when wildfires occur in rough territory not well known by suppression crews coming from outside the area. Other failures can result from lack of compliance with safety rules such as LACES protocol (Lookouts; Anchor point or Awareness; Communications; Escape Routes; Safety Zones; [130–132]. EWEs, due in large part to their inherent control challenges, can pose more risk for population, assets, and infrastructures, and can provoke entrapments and fire overruns with fatalities.

Hence, EWE is defined as:

> *a pyro-convective phenomenon overwhelming capacity of control (fireline intensity currently assumed $\geq$ 10,000 kWm^{-1}; rate of spread >50 m/min), exhibiting spotting distance > 1 km, and erratic and unpredictable fire behavior and spread. It represents a heightened threat to crews, population, assets, and natural values, and likely causes relevant negative socio-economic and environmental impacts.*

4. A Preliminary Proposal of Extreme Wildfire Event Classification

Table 3 is a first attempt to build a scale of gravity for wildfires similar to that used for tornados (Fujita scale), and hurricanes (Saffir-Simpson scale). In this wildfire classification, the first four categories are labeled as *normal fires* (i.e., events within the general capacity of suppression as dictated by technological and physical constraints) ([28]; p. 23), while the other three exceed that threshold and are classified as EWEs, integrating the descriptions of recent extreme wildfire events [84,118] with consolidated literature [125]. The necessity of a scale for wildfires is considered "a worthwhile endeavor" ([21]; p. 50).

The criteria used to establish this classification were real time fire behavior measurable parameters, and real time observable manifestations of EFB. In the former the parameters selected were FLI and ROS and for each category of wildfire quantitative thresholds are considered. In the latter, pyroCb, downdrafts, spotting activity and distance, and flame length (FL) were considered with quantitative and qualitative values. FL is sufficiently easy to assess at the practical operational level [133] and provides a quick assessment of FLI, because of the interdependence of the two parameters [95].

In the proposed EWE classification there is no mention of impacts (environmental, social and economic) because they are highly influenced by the geographic characteristics of the affected area (e.g., WUI, rural space) and its vulnerability to wildfires. The vulnerability concept has been used with different meanings in wildfire literature [134]; it is here defined as the intrinsic characteristics and conditions of population and assets that create the likelihood for negative impacts. It results from the exposure, susceptibility, and capacity to respond to the specific situations. Distinctive degrees of vulnerability create different levels of damages and losses in similar conditions of exposure to wildfires of the same magnitude [135]. This suggests that there is a complex and nonlinear relation between the magnitude of fire and its impacts on society and environment.

Similarly, the use of biophysical parameters to classify EWEs should not be interpreted as a dismissal of the long term and complex social-ecological interactions that cause EWEs and contribute to their outcomes. In many cases, the ultimate causes of EWEs may be almost entirely anthropogenic, from the timing and placement of ignitions to the types and spatial patterning of the fuels, to the climate factors responsible for the conditions of fuels [136–138]. However, a scale of gravity for describing wildfire events need not distinguish between the degree of biophysical versus human causes.

Table 3. Wildfire events classification based on fire behavior and capacity of control.

	Fire Category	Real Time Measurable Behavior Parameters			Real Time Observable Manifestations of EFB				Type of Fire and Capacity of Control *
		FLI* (kWm^{-1})	ROS (m/min)	FL (m)	PyroCb	Downdrafts	Spotting Activity	Spotting Distance (m)	
Normal Fires	1	<500	<5 [a] <15 [b]	<1.5	Absent	Absent	Absent	0	Surface fire Fairly easy
Normal Fires	2	500–2000	<15 [a] <30 [b]	<2.5	Absent	Absent	Low	<100	Surface fire Moderately difficult
Normal Fires	3	2000–4000	<20 [c] <50 [d]	2.5–3.5	Absent	Absent	High	≥100	Surface fire, torching possible Very difficult
Normal Fires	4	4000–10,000	<50 [c] <100 [d]	3.5–10	Unlikely	In some localized cases	Prolific	500–1000	Surface fire, crowning likely depending on vegetation type and stand structure Extremely difficult
Extreme Wildfire Events	5	10,000–30,000	<150 [c] <250 [d]	10–50	Possible	Present	Prolific	>1000	Crown fire, either wind- or plume-driven Spotting plays a relevant role in fire growth Possible fire breaching across an extended obstacle to local spread Chaotic and unpredictable fire spread Virtually impossible
Extreme Wildfire Events	6	30,000–100,000	<300	50–100	Probable	Present	Massive Spotting	>2000	Plume-driven, highly turbulent fire Chaotic and unpredictable fire spread Spotting, including long distance, plays a relevant role in fire growth Possible fire breaching across an extended obstacle to local spread Impossible
Extreme Wildfire Events	7	>100,000 (possible)	>300 (possible)	>100 (possible)	Present	Present	Massive Spotting	>5000	Plume-driven, highly turbulent fire Area-wide ignition and firestorm development non-organized flame fronts because of extreme turbulence/vorticity and massive spotting Impossible

Note: [a] Forest and shrubland; [b] grassland; [c] forest; [d] shrubland and grassland; *FLI classes 1–4 follow the classification by Alexander and Lanoville [125].

5. Extreme Wildfire Event and Wildfire Disaster

Social elements are a fundamental reason for consideration of an EWE definition: if it were not for the potential adverse social impacts of an EWE there likely would be little need to develop a consistent definition. In this respect, we feel it is important to overtly discuss distinctions between an EWE and their potential social impacts. Bowman et al. [1] distinguish between an EWE and a wildfire disaster, where the former is assessed by using a physical measure of fire behavior (i.e., radiative power, FRP in MW/pixel) and the latter by measurable socio-economic impacts (i.e., firefighters or civilian casualties and damage to property and infrastructures) and with reference to institutional procedure (i.e., the official declaration of a disaster by a national government). We agree that EWEs should be operationally differentiated from disasters, because an EWE does not necessarily become a disaster. A wildfire disaster can be the consequence of an EWE, but it can also be the consequence of a controllable phenomenon (a *normal wildfire event*) because of inadequate management of control actions (e.g., lack of resources, lack of coordination between emergency teams, wrong instructions, wrong evaluation of situations), lack of preparedness by concerned communities, poor land management that has not adequately modified fuel continuity (Figure 2). Conversely, individual large fires simultaneously burning that compete for resources, decrease the likelihood of early fire control and thus increase the chances that any given event will become an EWE or even a disaster [49].

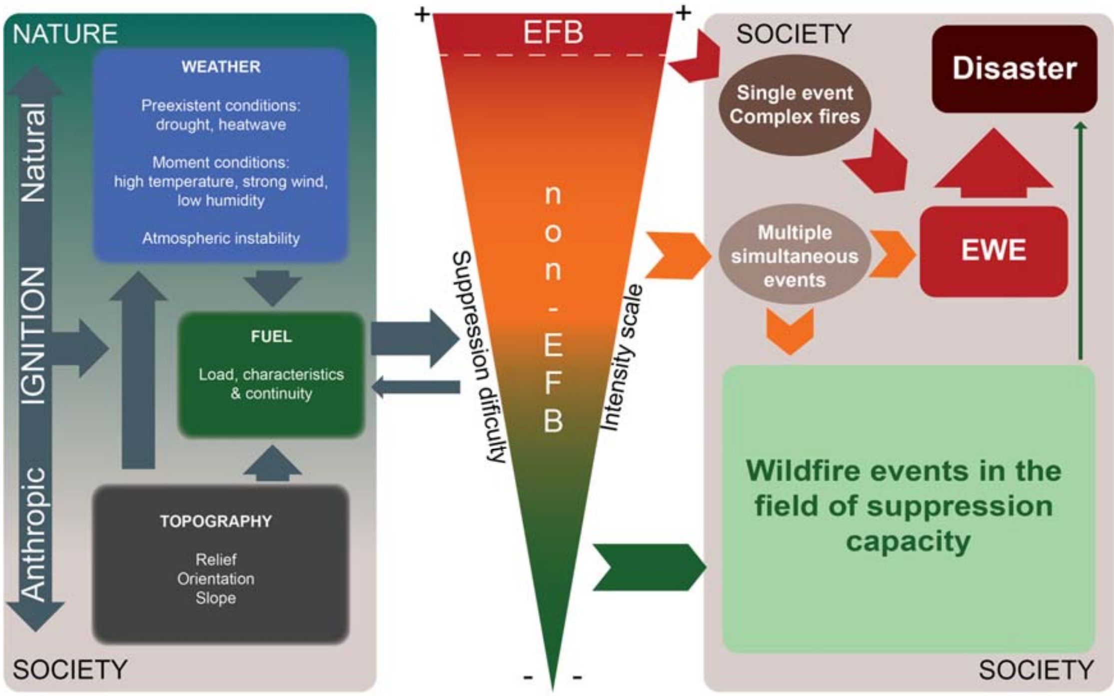

Figure 2. EWEs and wildfire disasters as social constructs. The left rectangle shows a three-ways interaction: between physical components (e.g., weather) and fire; between people/society and fire (e.g., ignition); and between people /society and the physical components (e.g., land management, fuel reduction, silviculture, creation of roads, water points). The right rectangle represents a two-way relationship between fire and all the components of human system (e.g., individuals, communities, organizations, properties rights, legislation, planning, preparedness, mitigation, resources, culture) because EWEs are a threat to people and assets but people can attenuate the threat reducing the vulnerability and increasing the resilience. The word society synthesizes the plurality of processes, conditions and factors that interplay with fires in different cultural and geographical contexts.

A major consideration in this distinction is the degree to which people and what they value, and rely on for everyday functioning, is significantly affected by an EWE. Whether an EWE becomes a disaster is influenced by what societies and citizens do, individually and collectively, to anticipate sources of risk, act to reduce and manage the risk prior to events occurring, and develop the knowledge, resources, skills and relationships to facilitate their ability to cope with, adapt to and learn from wildfire events. Therefore, the purpose of wildfire management, situated at the interface between society and environment, is to take the necessary steps to avoid the occurrence of EWEs because they are not necessarily an ecological inevitability. In the case of their occurrence, management must ensure that the territory and population are prepared to face them, respond and recover from them. It is thus argued here that an EWEs can turn into a disaster if it directly effects and exceeds the coping and resource capacity of people and communities. This can include the following conditions:

(i) Social impacts. A serious disruption of the functioning of a community or a society at any scale, due to wildfires interacting with conditions of exposure, vulnerability and capacity to cope, leading to human, material, economic and environmental losses and impacts [89,139]. Mayner and Arbon [140] found the most consistent definition of a disaster to be the widespread disruption and damage to a community that exceeds its ability to cope and overwhelms it resources. The affected communities or societies must receive external support to reestablish normal life. The goal is not necessarily to "bounce-back". In an era of ever-increasing risk, the goal is more about adaptation (e.g., to the social, natural and built environment settings, changed economic conditions, climate change) to emergent realities and transformation (to develop more appropriate approaches to coexistence with fire). It is also important to recognize that disasters can cause direct and indirect impacts, and have both short- and long- term implications.

(ii) Psychological impacts. Disasters are potentially traumatic events that are collectively experienced, and often have an acute onset [141]. Even though a wildfire is a time-delimited event, its effects can be long lasting, and measured over months or years. While enduring trauma, acute stress and post-traumatic stress disorder (PTSD) are fortunately only experienced by a minority of people, stress and traumatic stress are characteristic of all disasters.

Stress and its consequences for wellbeing in people, families and social networks can occur over time, and not just during the period of event impact. Stress reactions are greater if events are perceived to be caused by human agency, especially acts of omission (e.g., failure to plan for a controlled burn that gets out of control) or commission (e.g., arson). Reactions are affected by threats to control beliefs and attributions of responsibility. These reactions can be found in the absence of fatalities and can affect those not present (i.e., those who could have been there, those who used to live in another area). In the case of an EWE occurrence, people do not necessarily die, but their livelihoods and sources of income can be severely disrupted. It is also important to accommodate the fact that the experience of challenging hazard events can transition into posttraumatic growth [142]. Stress triggered when dealing with recovery agencies (response generated demands), organizations, and government departments is greater than that experienced in the immediate aftermath of the event [143–145].

The importance of recognizing the direct linkages between the EWE definition and social factors, existing social conditions and potential negative impacts, is needed given the inherent social-ecological nature of wildfire [146,147]. These include the lack of governance systems and planning to cater for events that create large-scale destruction with significant and enduring social and economic disruption [145]. In addition, wildfire disasters create numerous social needs such as:

(i) need for temporary relocation (which can be measured in months or years while people await rebuilding efforts and this can create conflict from differences in how recovery is managed) or permanent relocation (this removes factors such as sense of community and place attachment, and can generate conflict if people are moved to other settlements);
(ii) loss of social network connections, so loss of sense of community, and social support;
(iii) loss of heritage, and community symbols, that threatens, or destroys place attachment and identity.

These demands are more likely with EWEs and so need to be accommodated in how EWEs are conceptualized and how policy and plans are developed and enacted.

6. Conclusion

EWEs are complex social-ecological phenomena requiring a transdisciplinary approach to understand what they really represent. Agreement on a common term and definition to label extraordinary fires is not a minor concern if the scientific community wants to effectively transfer knowledge to enhance wildfire management policies and practice. From the fire management point of view an agreed-on definition can more quickly help to identify fires that will exceed the current capacity of control, where suppression is impossible as long as fuel and weather conditions do not change. From a disaster risk reduction perspective, defining the social and ecological contributions to EWEs is fundamental to developing realistic and comprehensive estimates of risk and how risk can be reduced.

Finally, a clear definition of EWE highlights the fact that not all fires are the same and that some events are beyond the capacity of even well-resourced organizations to control. EWEs are very challenging and costly phenomena but they do not inevitably lead to disasters. Adequate and timely prevention measures can decrease the likelihood of EWEs occurrence, and mitigation activities and preparedness can increase safety and decrease potential losses and damages.

The EWE definition and wildfire classification proposed in this paper can facilitate communication not only within organizations concerned with wildfire management but also with the general public. In particular, the EWE definition allows for more overt recognition of the limits of suppression activities and clarifies key factors that contribute to extreme conditions. This knowledge can help both managers and members of the public identify actions that could best reduce the fire risk for both *normal* and *extreme wildfire events*.

This paper addresses the social-ecological topic (or the coupled human natural system topic) in a more appropriate way than many existing efforts. Developing a definition of EWE that incorporated more social elements would not only likely be artificially forcing non-comparable factors together (not dissimilar to categorical vs. ordinal) but also would be unproductive as the definition would be unlikely to be relevant in many contexts and/or have to remain so general that it would have minimal value. Instead, by clearly distinguishing how an EWE can be consistently defined in a way that is socially meaningful (e.g., ability to control) and then drawing out how an EWE can be linked with the broader social aspects defined in the context of disaster, we bring together the social and ecological in a meaningful and appropriate way.

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Appendix A

Table A1. Wildfire as a social-ecological process: stages. This table is a more detailed but not exhaustive list of processes, conditions and factors depicted in Figure 1.

Dimensions and Categories		Prevention and Mitigation	Ignition	Spread and Behavior
Human	Processes	Land management Forest and fuel management (e.g., controlled burning, defensible space) Disaster risk reduction (DRR): (i) Vulnerability assessment & reduction; (ii) Risk assessment and communication; localizing knowledge, beliefs and actions; (iii) Enhancing forest resilience; (iv) Enhancing individual, household, and communities' resilience; and (v) Planning to co-exist with a hazardous environment Public education & awareness Training Preparedness including business continuity planning Law enforcement	Deforestation Afforestation Industrial tree plantation Allocation of forest to alternative land use Urban sprawl Land conversion to crops Increasing demands for agricultural land Land clearing for cattle ranching and conversion to pastures Land abandonment *Slash and burn* agriculture *Slash and burn* forest removal *Scorched-earth* policy (political fires) Burning of fields and houses as measure to expel occupants Land use and natural resources conflictuality	Simulation and analysis of fire spread Operational orders

Table A1. *Cont.*

Dimensions and Categories		Prevention and Mitigation	Ignition	Spread and Behavior
	Conditions	Land use Land ownership and conflicts Wildland Urban Interface (WUI) Rural Urban Interface (RUI) Prevention infrastructures Relationship between community and fire management agencies Personal characteristics and beliefs (e.g., fatalism, outcome expectancy) Awareness	Knowledge of causes Early alert	Abandonment of landscape Landscape connectivity Prevention infrastructures Accessibility Mobility conditions Defensible space Multiple contemporary fire occurrence Firefighting crews' availability Operational capacity
	Factors	Behavioral, demographic, economic, organizational, political, and sociocultural. Legacy	Anthropogenic causes (Negligent, intentional, and accidental) Behavioral, demographic, economic, organizational, political, and sociocultural.	Behavioral, demographic, economic, organizational, political, and sociocultural.
Physical and Ecological	Processes	Secondary succession	Vegetation curing, shrinkage and wilting Moisture content of dead and live fuels (FMC & LFMC)	Fire behavior FMC & LFMC Vegetation curing, shrinkage and wilting
	Conditions	Fuel load and continuity	Dead fine fuel load Climate and Weather (C&W)	Fuel characteristics (Continuity, size packing, density, moisture content, mineral content, vegetation stage) C&W Topography Fire behavior
	Factors	Natural succession	Natural causes (Lightning, volcanism, self-combustion, meteorite fall)	C&W Topography

Table A1. *Cont.*

Dimensions and Categories		Suppression	Impacts	Recovery and Restoration
Human	Processes	Defense plans Organization of resources and means (Incident Command System) Strategies and tactics Mopping-up Communication system	Emergency response Casualties and injured people Damages of assets Community response Psychological aid Governance Livelihoods disruption Resilience Reporting damages protocol	Burned area emergency response (BAER): assessment and action Land management Planning to co-exist with a hazardous environment Post fire erosion mitigation Salvage logging Rebuilding assets Livelihoods and businesses continuity Governance
	Conditions	Land use mosaic Accessibility Mobility level of knowledge and information Operational capacity Communication system	Operational capacity WUI/RUI Vulnerability of people and assets Awareness	Government behavior Laws and regulations Financial resources availability Insurance Build *Fire Smart Territory* (FST)
	Factors	Behavioral, economic, organizational, political, and sociocultural.	Behavioral, demographic, economic, organizational, political, and sociocultural.	Behavioral, demographic, economic, organizational, political, and sociocultural.
Physical and Ecological	Processes	Change of fire behavior	Severity Biomass consumption Soil erosion Surface runoff	Natural regeneration Resilience
	Conditions	Atmosphere instability Fuel continuity (incl. natural vegetation gaps, e.g., the sea) Vegetal cover mosaic (including that created by past fires) Degree of vegetation curing	Vegetation species Wildfire duration Evolutionary stage of vegetal cover Hydrophobicity	Extent and duration of wildfire season Fire regime Past -fires Fire history
	Factors	Weather Topography	C&W Topography Soil properties	C&W Disturbing factors (e.g., animals; short return time of fires)

Table A2. The use of *extreme* in wildfire literature.

Fire	Term	Definition or Description	Scope
Danger and weather	**Extreme fire danger**	Fire danger rating usually includes an Extreme class. In the McArthur Forest Fire Danger Index (FFDI) "Extreme" has been redefined after Black Saturday as being between 75 and 100 [148]. In Europe (EFFIS) the Extreme class threshold for Fire Weather Index is 50 (Canadian FWI System).	Informs that conditions are favorable to fast spreading, high-intensity fire of erratic behavior, with the potential to become uncontrollable. Firefighters entrapments and fatalities can result. As a consequence, maximum preparedness (from fire prevention to fire suppression to civil protection) is planned for and implemented.
	Extreme fire weather Extreme fire weather days **Extreme weather conditions**	Fire weather conditions corresponding to Extreme fire danger or leading up to Extreme fire behavior, usually defined by the tail end of the fire weather distribution, e.g., FFWI (Fosberg Fire Weather Index) exceeding the 90th percentile [149]; days that have a fire danger rating of 50 or greater for at least one of the three-hourly observations [150]; days with air temperature ≥20°C at 850hPa [35].	
	Extreme fire days **(red flag days)**	The onset, or possible onset, of critical weather and dry fuel conditions leading to rapid or dramatic increases in wildfire activity [151,152].	Extreme fire behavior expected for the next 12 to 72 hours, imposing a red flag warning.
	Extreme wildfire burning conditions	Conditions leading to flame and lofted burning ember (firebrand) exposures, home ignition, and unsuccessful firefighting efforts [153].	Defines conditions of extreme fire behavior in order to declare ban of high risk activities, preventing human-caused wildfires and structure fires, protecting the natural environment and ensuring public safety.
Behavior	**Extreme fire behavior**	Comprises one or more of the following: high ROS, prolific crowning and/or spotting, presence of fire whirls, deep pyro-convection. Predictability is difficult because such fires often exercise some degree of influence on their environment and behave erratically, sometimes dangerously" [72,74,82,154–156].Fire with intensity >4000 kWm^{-1} [157].	Defines conditions and fire characteristics that preclude methods of direct, or even indirect, fire control.
	Extreme fire event **Extreme wildfire event** **Extreme bushfire**	Conflagrations associated with violent pyroconvective events. These extreme wildfires can produce pyroCb, thus a fire-caused thunderstorm [2,21]. Extreme bushfire: a fire that exhibits deep or widespread flaming in an atmospheric environment conducive to the development of violent pyroconvection, which manifests as towering pyroCu or pyroCb storms [13,20,82,156].)	Definition of extreme wildfire based on local fire-atmosphere interactions.
	Extreme fire-induced winds	Winds generated by low-pressure regions at the flame front. In case of large fires, with the formation of special clouds called pyro-cumulonimbus (pyro CB) [113,158].	Atmospheric instability descriptors define increased danger in firefighting in relation to continuously changing headfire conditions; unexpected, intense fire behavior on the flanks and back of the fire.
	Extreme rates of spread	Value considered extreme: 33 ft /min [159]; 150 ch/h [117] (respectively 10 and 50 m/min.	A component of wildfire hazard based on ROS, FL and suppression effectiveness. Allows evaluating whether a fire can be suppressed and which types (and amount) of resources will be effective.
	Extreme fire phenomena	A poorly defined term [160,161].	NA
	Extreme landscape fire	A form of natural disaster [12,68,91,162–164].	NA
	Extreme fire (burn) severity	Fire severity is the overall immediate effect of fire resulting from the downwards and upwards components of heat release [165] and can refer to the loss or decomposition of organic matter [166], and in general to the impacts of fire on vegetation and soil. Recently the concept has been enlarged to social impacts [166–171].	Assessment of wildfire impacts. Allows to evaluate the needs of emergency recovery measures and prioritize their distribution within the burned area, as well as to plan other post-fire activities, e.g., salvage logging.

Table A2. *Cont.*

Fire	Term	Definition or Description	Scope
Risk	**Extreme wildfire hazard**	Hazard assessment based on scoring community design, vegetation, topography, additional rating factors, roofing materials, existing building construction, fire protection, utilities, https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1302.pdf	Used to assist homeowners in assessing the relative wildfire hazard severity around a home, neighborhood, subdivision, or community. The value of extreme is for 84+ points.
	Extreme wildfire hazard severity	The maximum severity of fire hazard expected to prevail in Fire Hazard Severity Zones based on fuel, slope and fire weather, http//www.fire.ca.gov/fire_prevention/fire_prevention_wildland_faqs	Identification of maximum severity of fire hazard to define the mitigation strategies to reduce risk.
	Extreme wildfire threat	The Wildfire Behavior Threat Class estimates potential wildfire behavior. An Extreme (Red) class consists of forested land with continuous surface fuels that will support intermittent or continuous crown fires [172].	Integrates many different aspects of fire hazard and risk and provides spatially-explicit tools for understanding the variables that contribute to wildfire threat.
Regime	**Extreme fire regime**	The time series of the largest fire (i.e., area burned) per year [173].	Term used for statistical purposes.
	Extreme fire seasons	The period of time when fires typically occur or when they are likely to be of high intensity or burn large expanses [174].	Supports fire prevention and preparedness based on fire-promoting conditions (drought, solar radiation, relative humidity, air temperature) that have extreme values, e.g., the 90th percentile.

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