Severe Forest Fires: Assessment Methods and Reclamation Techniques

Luís Loures; Susana Dias; Tiago Ramos; José Nunes and Ana Viegas

Abstract **-** Fire effects on soils result from the combination of the amount of heat released (fire intensity) and its duration. This combination between fire intensity and duration is denominated as fire severity, and it is used to measure the effects of forest fires. Fire severity and intensity have been commonly considered synonyms, however this is a mistake as fire intensity is a component of fire severity, being related to the amount and rate of fuel consumed, and therefore not being representative of the total amount of energy produced during the forest fire process. The most influent component of fire severity is fire duration as lower intensity and slow movement fires causes more damages than fast and high intensity fires. This research addresses effects and impacts of forest fires not only in soil, properties considering short-term, long-term and permanent changes depending on type of property affected, fire severity and frequency, and climacteric conditions after fire, but also on water properties, which are less known, harder to visualize, and more difficult to comprehend and assess. Additionally this research presents some practical examples of landscapes affected by severe forest fires assessing both the methods and techniques used on their reclamation, and their advantages and disadvantages.

Key-Words - Forest fires; Soil layers; Reclamation Techniques; Landscape Assessment.

I. Introduction

THIS study will focus on explaining the effects of forest fires on soil and water, as these effects are less commonly known and harder to visualize, comprehend and assess.

Soil is arranged according to horizontal layers, named as horizons, which display different properties and characteristics related to interactions between water, air, minerals and organic matter, which characteristics are deeply affected by fire.

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However, the horizon most affected by forest fires is the O horizon, being the first and top horizon in soils profile it is composed by three layers of organic matter in different stages of decomposition. The L (litter) layer, being the first layer, mainly consists of fresh and non-decomposed organic matter, followed by a layer of mostly decomposed organic material, known as F (fermentation) layer.And lastly, the H (humus) layer, made up of totally decomposed organic matter. However, this three layer disposition is now usually aggregated in only two layers, being the L layer, denominated as O_1 or litter and the F and H layer combined, known as O_2 or duff [1].

This horizon may be mineralized or consumed through mineralization, due to high temperatures associated to large forest fires, which can result in mineral soil exposure, nutrients transformation, ash accumulation and water repellence (hydrophobicity) [2]. The main reason why the lower layers are not as much affected is due to the fact that dry soil is a bad electricity conductor, and although temperatures during a forest fire may reach 900°C, 5 cm below surface, temperatures usually don't exceed the 150°C [3].

Fire effects on soils result from the combination of the amount of heat released (fire intensity) and its duration. This combination between fire intensity and duration is denominated as fire severity, and it is used to measure the effects of forest fires [4] (table 1). Fire severity and intensity have been commonly considered synonyms, however this is a mistake as fire intensity is a component of fire severity, being related to the amount and rate of fuel consumed, and therefore not being representative of the total amount of energy produced during the forest fire process [5]. The most influent component of fire severity is fire duration as lower intensity and slow movement fires causes more damages than fast and high intensity fires [6]. Fire severity is a qualitative term which represents the magnitude of *change* caused by fire on both underground and superficial ecosystem components [1].

The resulting effects depend on interactions between combustibility and amount of fuel, type of vegetation, intensity (released energy), duration, climate, topography and burnt area [6]. Due to the fact that fire severity is classified only qualitatively, several authors have established three severity classes, being low, moderate and high, which in turn express the range of impacts caused by fire on ecosystem components like amount of organisms affects, the proportion of dead trees and shrubs, or the amount of new tree sprouts [5].

Soil and Litter Parameter	Burn Severity		
	Low	**Moderate**	**High**
Litter	Scorched, Charred, Consumed	Consumed	Consumed
Duff	Intact, Surface Char	Deep Char, Consumed	Consumed
Woody debris – Small	Partly Consumed, Charred	Consumed	Consumed
Woody debris- Logs	Charred	Charred	Consumed, Deeply charred
Ash Color	Black	Light Colored	Reddish, Orange
Mineral Soil	Not Changed	Not Changed	Altered Structure, Porosity, etc
Soil Temp. at 10 mm	<50 °C	100-200 °C	>250 °C
Soil Organism Lethal Temp.	To 10 mm	To 50 mm	To 160 mm

Table 1 - Burn severity classification based on post-fire appearances of litter and soil and soil temperature profiles. Developed after Hungerford (1996) and De Bano *et al.* (1998) in Robichaud *et al*. (2000)

Soil properties may suffer short-term, long-term and permanent changes depending on type of property affected, fire severity and frequency, and climacteric conditions after fire [7]. These changes may produce different responses regarding the several ecosystem components - fauna, flora and water - due to its complex interactions.

Soil analysis regarding post-fire effects is usually the best indicator to reveal fire severity and consequent rehabilitation measures related to watershed management and soil damage mitigation [2]. Severe forest fires cause impacts on soils physical, chemical and biological properties. As such, the main alterations on physical properties are hydrophobicity (water repellence), decreased structural complexity and increased erosion and runoff (Fig 1).

Fig 1 - Hydrophobic soil after fire. Source: Forest Service, USDA

While decreased organic matter content and exchange capacity, and changes on nutrients cycles constitute the main chemical changes. Regarding the biological alterations, microbial and soil-dwelling invertebrate's biomass is decreased and its community composition is altered [7]. Large forest fires mainly affect and change water quality and processes of the hydrological cycle, such as, interception, infiltration, evapotranspiration, soil water retention capacity, and surface runoff. These changes are related to fire severity, duration and frequency [4]. So it is necessary to comprehend these variations in order to elect the adequate rehabilitation measures.

Increased sedimentation and turbidity, water temperature and nutrients concentration, are the main changes affecting water quality after large forest fires [8]. The absence of the organic matter layer consumed by fire may also result in increased concentration of bacteria and microorganisms, as this layer work as a filter which intercepts them from infiltrating in soil and watershed system [5].

Regarding watershed processes, surface runoff during the first post-fire raining period presents the largest threat to soil and hydrologic processes. Infiltration, interception and water retention capacity are decreased due to lack of ground vegetation and organic matter, and possible soil hydrophobicity, which in turn result in higher surface, stream and storm flow causing larger erosion rates and higher flood risk [1].

II. Damage Assessment Methods

Although there are several methods that have been developed in order to evaluate the effects of forest fires, the ones developed by The United States of America, and by The European Union, are generally considered the most relevant and developed ones for nationwide use. In this regard the present study will focus these two methods, developing a comparison study in order to identify the ways they are applied, their main strengths and weaknesses, and their advantages and disadvantages in terms of cost, effectiveness, adaptability, etc..

A. Landscape Assessment - FIREMON

Landscape Assessment method is part of the FIREMON program, which constitutes a system of fire effects monitoring and inventory. This method measures the fire severity, through integration of two methodologies, Burn Remote Sensing (BR) and the Burn Index (BI). The development of this method by Carl H. Key and Nathan C. Benson, started in 1996, after Glacier National Park fire in 1994, e since then it has been improved in order to operate and be effective for national use (Fig 2). As such, the first version was available in 2001, being slightly changed in 2002 and 2003 [9].This method aims to identify and quantify fire effects, in order to be able to aggregate and compare spatially and temporally the resulting data. Results revealed by this method enable the observation of forest fires spatial heterogeneity and how fire interacts with both vegetation and topography.

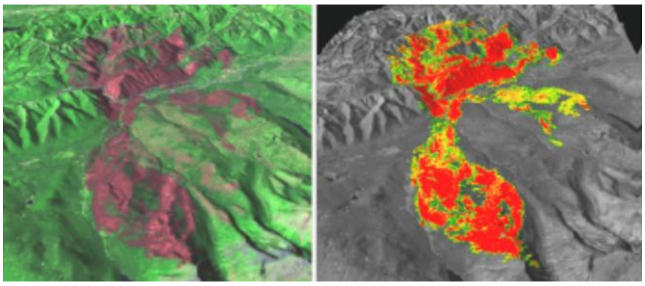

Fig 2 - A 3D view of the Moose fire, taken by Landsat ETM+ on 9 September 2001. On the left, spectral Band 4 and Band 7 are displayed as a composite of green and red, respectively. On the right, differencing the NBR before and after fire has derived an initial assessment of burn severity. The gradient of differenced NBR has been stratified to identify burn severity levels. Source: Forest Service, USDA

The multispectral data from Landsat comprehends several data about Earth characteristics, in which each individual spectral band responds individually to different superficial features, such as vegetation structure, mineral composition and water content, being then isolated and analyzed through combination of mathematic algorithms with the range of brightness levels.

Severity is assessed by combining two methodologies, remote sensing from Landsat 30-meter data and a derived radiometric value denominated as Normalized Burn Ratio (NBR) (Fig 3). In order to obtain the mapping of the severity, NBR is temporally differenced between pre and post fire data, resulting in the *change* detected from fire, known as differenced Normalized Burn Ratio (dNBR) [9]. This approach consistently separates burned from unburned areas, and optimally classifies a broad gradient of fire-effect levels within the burn [9].

As stated before this method consists on the detection of *change* caused by fire, therefore it is imperative to colect data before and after fire in seasons where the phenology and moisture content are as similar as possible. This is due to the fact that landscape are in constant evolution and transformation through its diverse cycles of productivity [9].

The alteration observed in the landscape immediately after fire are related to burnt, carbonized and consumed vegetation and fuels, and also the soil exposure and ashes levels, being these alterations the majority of the fire severity indicators. However, there are important changes that are only visible later, like vegetation recovery and delayed mortality.

Consequently there are two evaluation and comparison strategies, the initial and the extended assessment, which present different results, considering the study objectives. Initial assessment aims to observe the effects immediately after fire, while the extended assessment, which is considered to be the most representative for real severity assessment, aims to evaluate the *change* caused by fire on the following growing season.

The other methodology, Burn Index (BI), serves as a complementary study, in order to validate and tune results obtained from remote sensing, and can also be used in stand-alone studies. BI uses a plot sampling method in which up to five vertical levels, denominated as strata, and representing the different layers of the vegetation community, are assessed within each plot in order to obtain the severity levels for each strata, and subsequently for each plot. The plot layout is determined by setting 10 to 20 plots randomly or non-randomly for each severity level determined, in areas that show reduced dNBR spatial variation [9].

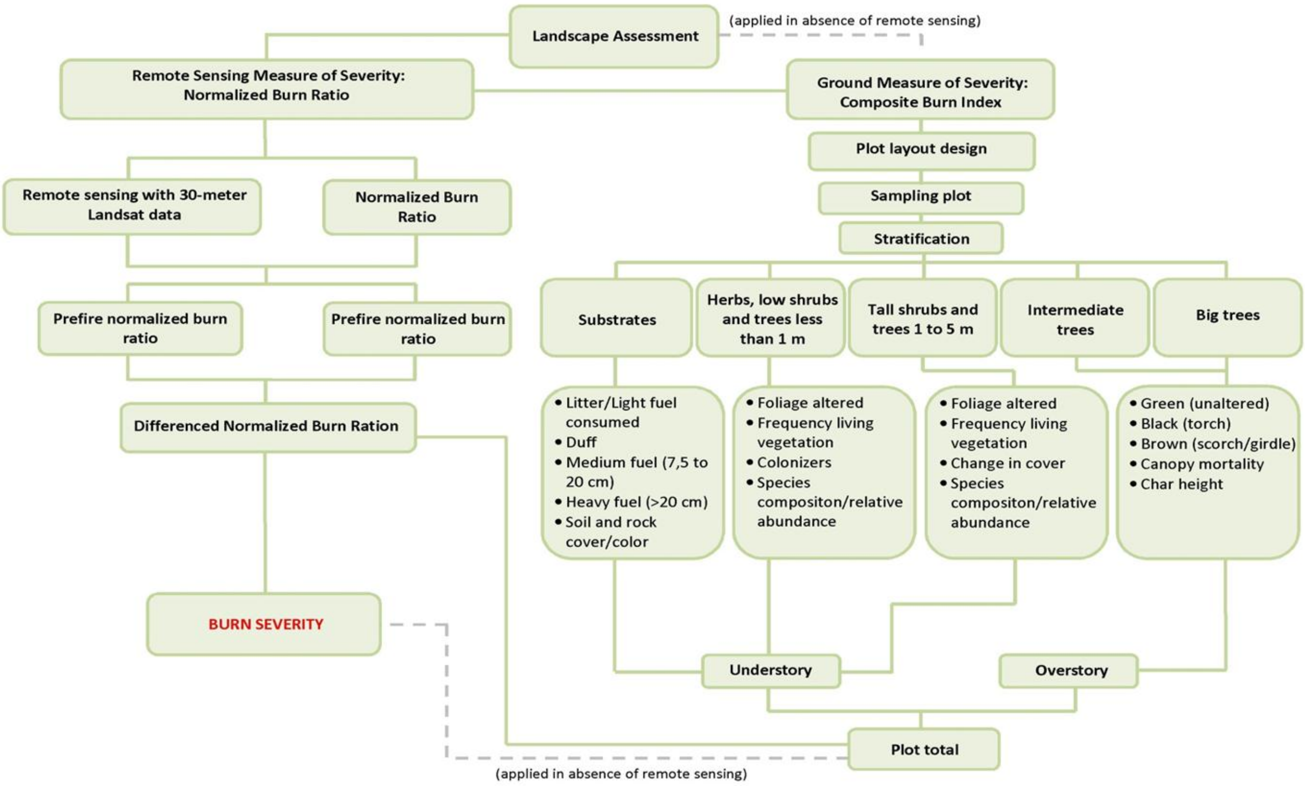

Fig 3 - Representative scheme of the Landscape Assessment method. Developed by the authors – all rights reserved.

The BI classification varies between 0.0 (not burned) and 3.0 (maximum burn effect) and evaluates certain aspects, such as, soil condition, amount of consumed vegetation and establishment and development of new vegetation species.

Therefore BI represents the magnitude of effects across all strata and layers of a specific sampling plot, allowing the correlation and validation of the remote sensing data.

for each plot, five indicators are calculated using specific values from the collected data, which are:

- Indicator I – Relative burnt volume;
- Indicator II – One year survival probability of trees;
- Indicator III – Importance of regeneration;
- Indicator IV – Erosion aggravation risk;
- Indicator V – Fire intensity.

Each indicator will have an integral value between 0 and 4, being 0 no fire effects and 4 maximum fire effects, and computation of these values will result in plot severity level, and consecutively the whole study area [10] (Fig4).

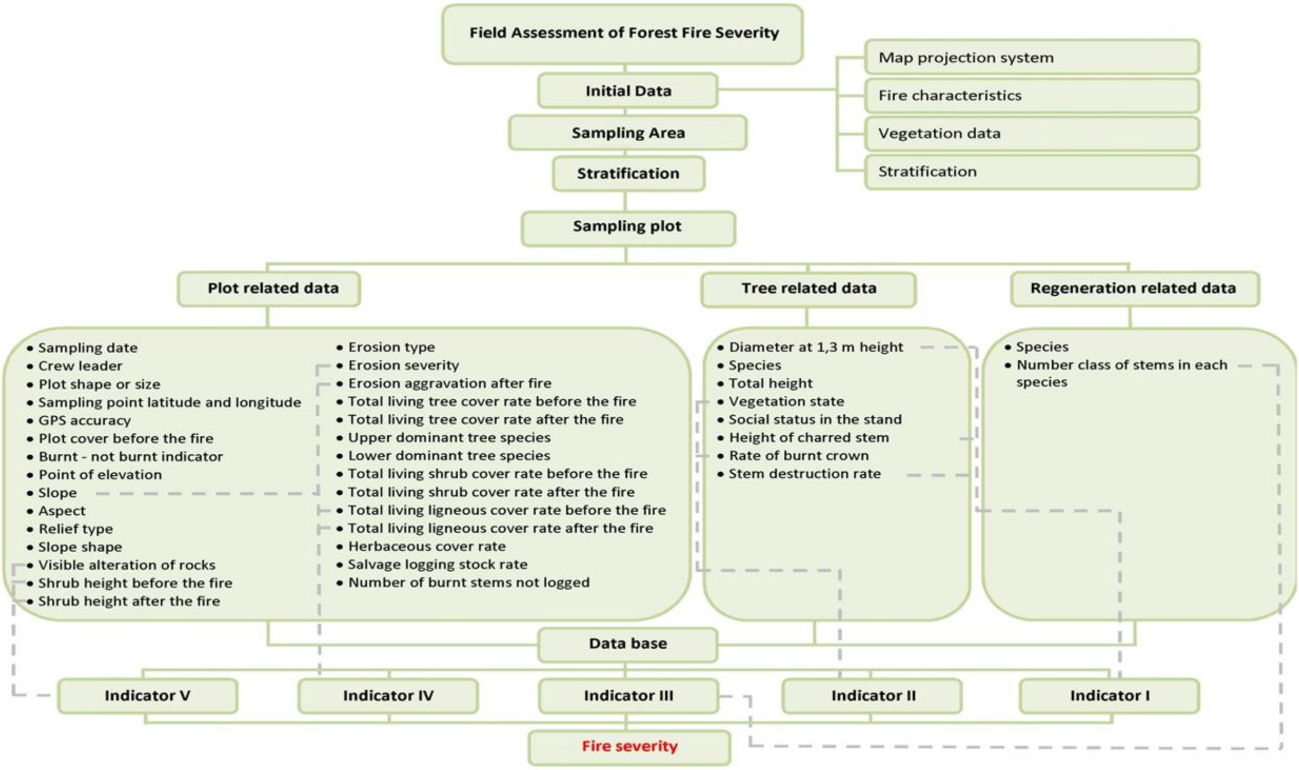

Fig 4 - Representative scheme of the Field Assessment of Forest Fire Severity method. Developed by the authors – all rights reserved.

B. Field Assessment of Forest Fire Severity - ForFireS

The method of Field Assessment of Forest Fire Severity (ForFireS), was developed by the European Union, inserted in the European Forest Fire Information System, in order to implement mechanisms for forest conservation and protection which objective is to establish a fire severity assessment method which can be used by its Member States, for forest fires superior to 50 ha, allowing this information to by compiled and shared between users [10].

ForFireS is a sampling method which compiles initial data, regarding map projection, fire characteristics, data about burned vegetation and a possible stratification, which in this case is horizontal, determining similar vegetation communities rather than vegetation layers as mentioned in the previous method. In order, to assess fire severity, this method uses the initial data to establish a plot layout following a specific process, enabling an extensive analysis and data collection from each plot.

The data collected regards information about the sampling plot and its condition, trees and vegetative regeneration [10]. Afterwards, to obtain the severity level

III. Reclamation Techniques

In order to mitigate damage from severe forest fires, it is necessary the program specific interventions on the affected areas. Therefore, considering the objective of this study, it is important to approach and describe the most common and frequently used rehabilitation measures and criteria, as well as, showing previous studies that determine the most objective measures, in terms of effectiveness, time and costs.

In general terms, short term and urgent rehabilitation measures for post-fire areas consist essentially on slope and channel/corridor treatments. Although there are several other techniques, the most common ones according to the performed analysis are logging, seeding, mulching, and contouring, which may suffer alterations in its components or applications. For example, there are several types of mulch, as well as several types of contouring structures with different components, whether it is straw or logs, and with different uses, some may be used for channel treatments or slope treatments.

Therefore, we proceed to a concise explanation of the following techniques, as well as some of its benefits and potential damages:

- *Logging*: even though logging is not considered in several studies as a rehabilitation measure, it is commonly used, despite its controversy regarding its relation between benefits and damages. The economic aspect seems to be the most relevant, as logging generates jobs and provides monetary benefits which can be used for treatment of the affected area. As for the ecological side, the residues left by logging reduce overland flow [11] however other studies consider that it increases erosion rates [12]. Also, despite reducing the amount of available fuel [13] this measure damages soil structure and nutrients cycle from tasks inherent to logging [12], and also reduces the habitat diversity as well as conditions for its development [14]. Other controversial point is related to the fact that is commonly cited that logging reduces potential insect pest [15] however recent studies show that insects prefer slightly burned trees, which should not be logged, to severely or completely burned trees [16];

Fig 5 - Contouring made with straw wattles. Source: Forest Service, USDA

- *Seeding*: consists on both ground and aerial distribution of seeds of grasses, aiming to reduce erosion rates, increase ground cover and control the establishment of non-native plants [17]. However, this technique in order to succeed depends highly on season, intensity and amount of rain, as well as, nutrients erosion rates [18], hence why this type of treatment presents ambiguous effectiveness results. Problems associated with this technique are obviously the difficulty to correctly apply the measure, competition with native plants [17], as well as short term reduction on autochthone vegetation ground cover;

- *Mulching*: is usually used in agriculture, in order to control soil moisture and temperature, considering that it allows the improvement of its structure and nutrients content. However, this technique has also been used for post-fire treatments, consisting on application of either hydromulch, which enables larger consistency and compaction, or drymulch, consisting of straws and ligneous residues [19]. This technique presents several benefits, such as reduction in erosion rates, surface runoff, and compaction, and an increase in water infiltration rates [20, 6]. Regarding its disadvantages, they are its expensive cost [6] and the possibility of introduction of non-native species [20] therefore it is important to obtain mulch from a controlled and certified source;

- *Contouring*: consists on a technique that might apply natural and/or artificial materials, which have been used for decades to minimize impacts associated to surface runoff and erosion [6] (Fig 5 and 6). It is achieved by the application of retention structures placed along contour lines, mostly made out of logs, rocks, twigs and straws, being used both for slope and channel treatment. These structures contribute to sediment retention, surface runoff reduction and water infiltration increase [5, 6, 21, 22] as its main benefits. Regarding the negative aspects, this technique is costly and contributes to terraces development [6].

Fig 6 - Channel treatment with logs and straw bales barrier.

Often after applying emergency measures, due to severe effects on the ecosystem affected, there is the necessity of restoration of some or all of the ecosystem components, being them soil, water and vegetation. This process aims to improve certain components that, although being possibly treated, still present problems or deficiencies.

These measures can be considered as medium or long term measures, and regarding soil restoration, there are measures to improve its physical and chemical properties. As physical corrections, the most used methods are hydrogels and mulching, previously referred. Hydrogels emerged in the United States of America in the 50's, and are able to absorb e retain large amounts of water comparing to its volume, being later used in agriculture [23].

Biosolids use for chemical correction and soil fertilization is the most common method used, enabling an improved vegetation development, however this technique may lead to an increase in salinity, and in case of use of semiliquid muds, may also cause problems in the physical properties of the soil as mud dries [24].

Water flows are affected by combination of the effects caused on its components, like the roots of the riparian vegetation that maintain soil structure, and prevent erosion, or tree canopies that affect water temperatures through its shadows, or the vegetation that increases evapotranspiration [25].

Fig 7 - High severity fire in Grand Mesa, Uncompahgre and Gunnison National Forests, where emergency and long term measures will probably have to be applied. Source: Forest Service, USDA

As well as in soil restoration, in case of high erosion and sediment transportation rates, it is necessary an emergency intervention on water courses. The most used measures consists of barriers (referred previously in contouring), which may be called as sediment retention structures, enabling the reduction in water flows and sediment retention, which will be gradually released with the structure degradation.

Reforestation is a very important task in the vegetation recovery process, as it will establish the future use for the burnt area, as well as influence the potential for future fires. Reforestation plans in the last decades present ambiguous criteria for species selection, choosing either native or exotic, and softwood or hardwood species, being this ambiguity related to local characteristics and intended use. For example, if the future use intended is conservation, it is natural the use of native species, this affects also the methods and propagation steps [24].

IV. Case Studies

After considering fire effects, assessment methods, and reclamation techniques, it is important to analyze actual situations where these techniques were applied. In this regard the case study method was applied since it is considered a proficient tool to evaluate and access practical cases and approaches [26, 27, 28, 29 and 30].

In order to select the more adequate case studies we considered the rehabilitation projects developed in Portugal during the year of 2010, based on the reports elaborated by the entities that required subsidies to promote the rehabilitation of burnt areas, under PRODER program (Fig 8).

The data used for this analysis was collected from 16 reports which compile the type, amount and cost of the emergency rehabilitation measures required, for each case along the country, with particular incidence to the Center and North, probably due to the higher slopes and precipitation levels present with these areas, which associated to a lack of ground cover and vegetation will result in high erosion rates.

Fig 8 - Location of the 16 case studies selected. Source: Authors

Based on the emergency reports referred previously, a compilation of the available data was developed in order to elaborate conclusions out of the out coming results. However, the study is limited by the absence of information regarding effectiveness of the applied measures, which are very important as it is shown by several studies which conclude that rehabilitation measures present ambiguous results, and that there is a high level of complexity behind forest fires recovery.

In table 2, where a compilation of the collected data is presented, it is possible to conclude that the most common rehabilitation measures used for the year of 2010 in Portugal were: channel clearing, channel passages clearing, channel slopes setting treatment and road slopes setting treatment. This shows that channel stabilization and intervention is the first line of defense for forest fires rehabilitation.

Regarding costs it is possible to observe that mulching and logging, shattering and application, are the two techniques that presented the largest total costs, despite not being considered as the most used measures. This is due to the fact that these treatments are expensive; however, as stated by several authors present positive and consistent results in sediment retention and erosion prevention.

	TOTAL				
Burnt area (ha)	39893				
Intervention área (ha)	38899				
	Used	Unit	Amount	Value (€)	Total Value (€)
Channel clearing					
Channel clearing	16	ha	1282,8	200	256560
Channel passages clearing	15	nr	4858	50	242900
Dead trees logging	12	ha	955,9	55	52574,5
INTERVENTION ON SLOPES AND CHANNELS					
Logging	9	ha	2794	40	111760
Manual seeding	7	ha	1930	400	772000
Aerial seeding	2	ha	820	300	246000
Channel slopes setting treatment	16	ha	1180,9	200	236180
Surface overland flow correction	13	km	933,4	100	592840
Road slopes setting treatment	16	ha	711,8	50	135490
Contour bio-rolls	0		0		0
MULCHING					
Mulching	8	ha	2142	500	1071000
Logging, shattering and aplication	14	ha	2877	500	1438500
Contour bio-rolls	0		0		0
WATER REPELLENT LAYER DISRUPTION					
Water repellent layer disruption	2	ha	737	100/150	85950
ROAD CLEARING					
Dead trees logging	10	nr	1915	10	88450
Rocks and debris clearing	6	ha	152	100	15200
OTHER TYPE OF INTERVENTION					
Clearing and protection of wells	1	nr	50	50	2500
TOTAL (€)	5347904,5				
Cost/Area Ratio (€/ha)	137,5				

Table 2 - Compilation of the data retrieved from the 16 reports analyzed. Developed by authors.

After a general analysis we proceeded to analyzing two case studies more precisely, and selected them based on their dimension, being one a small forest fire and the other a very large one, in order to compare the costs associated to different areas.

The first forest fire was located in Amiais de Cima, with an area of 208 ha, it started in 3/8/2010 and had a duration of 10 hours, presenting a ratio between cost and area of 160.6 €/ha and total cost of 33400€.

The area consists of arborized area of basically eucalyptus, pines, and cork trees, being also present some uncultivated areas from previous agricultural use, consisting now of bushes of holms and *Quercus coccifera*, which prevented the fire propagation. It is also important to refer that the affected area present very steep slopes (>20-30%) being important a quick intervention in order to mitigate impacts before winter rains.

The second case study is located in Carvalhal da Louçã, with an area of 9786 ha, it had a duration of 7 days, starting in 10/8/2010, and presenting a cost/area ratio of 86.3 €/ha and a total cost of 844880 €.

The affected area is in its majority an area with mild slopes, with steeper slopes next to the Mondego River. Regarding vegetation, uncultivated areas are predominant, being these areas the ones with higher risk of increased erosion rates, when they are located next to the river with steep slopes.

V. Discussion and Conclusions

Considering the obtained results regarding the array of rehabilitation measures that have been compared and studied in terms of results, costs, effectiveness, risk of failure and installation, compiled in tables 3 and 4, it is possible to pinpoint that the most effective method for slopes treatment is mulching, however one should bear in mind the high costs associated to its implementation of this treatment on larger areas, which in turn are considerably smaller for aerial seeding that is a much cheaper treatment. However this method presents ambiguous results, as we can see on table 4, this fact is associated to its high difficulty to be correctly implemented, as referenced before.

Treatment Type	Cost ($ yd^{-3})	($ m^{-3})	($ ac^{-1})	($ ha^{-1})	Efficacy Category	Install Rate	Risk of Failure
Slope Treatment Summary							
Aerial Seeding	$23	$23	$79	$196	Moderate[1]	Rapid	Moderate
Mulching	$50	$52	$504	$1245	High[2]	Slow	Low
Countour felling	$180	$183	$720	$1778	Low[2]	Slow	High
Channel Treatment Summary							
Straw Bale Check Dams	$105	$107	$158	$392	High[2]	High	Low
Log and Rock Check Dams	$33	$33	$1346	$3325	High[2]	Slow	Moderate

Table 3 - Comparison of slope and channel BAER treatments. Source: Robichaud (2000)

[1] Estimated soil loss using Universal Soil Loss Equation (USLE)
[2] Estimated soil loss locally measuring

BAER Treatment	Number	Excellent (%)	Good (%)	Fair (%)	Poor (%)
Hillslope Treatment					
Aerial Seeding	83	24.1	27.7	27.7	20.5
Countour Felling	35	28.6	37.1	14.3	20.0
Mulching	12	66.8	16.6	16.6	0.0
Ground Seeding	11	9.1	81.8	9.1	0.0
Silt Fence	8	37.5	62.5	0.0	0.0
Seeding and Fertilizer	4	25.0	0.0	50.0	25.5
Stream Treatment					
Straw Bale Check Dams	10	30.0	30.0	30.0	10.0
Log Grade Stabilizers	10	30.0	30.0	10.0	30.0
Channel Debris Clearing	7	0.0	71.4	0.0	28.6
Log Dams	5	40.0	60.0	0.0	0.0

Table 4 - BAER treatment effectiveness ratings from individual fires as provided by interviewees. Source: Robichaud (2000)

On the other hand, contour felling is the most expensive treatment but presents ambiguous results as well, presenting a high effectiveness during the first year and for areas with high erosion rates [12]. Regarding channel treatments, straw bale check dams shows low costs and has high effectiveness and installation rate, which means that, this method is the most adequate for post-fire channel treatments in general. It is also worth mentioning the results demonstrated by log grade stabilizers, which present good results, despite its lower installation rate and its higher costs for larger areas. The general ambiguous and disperse results only shows the high complexity associated to post-fire treatments implementation, this is due to need of adjustment and consideration for each specific ecosystem condition. Results show that treatments which worked and presented good results overall may in other location not work at all, enhancing the experience and know-how needed for postfire rehabilitation.

Logging, though initially considered in several studies as a rehabilitation measure, in recent years has not been considered in recent studies, such as the ones mentioned before, since research has proven that it causes more damages than benefits and should only be used in cases where there is the intention to change current soil use, or to introduce a new arboreal community in the affected area.

Regarding fire assessment methods, it was possible to put forward several noteworthy ideas, namely that:

- Even if the method used in Europe (EU) is more extensive in its contents, it uses only a small part of the data collected in order to determine the fire severity, while the method developed in the United States (USA) uses all data collected both *in situ* and by satellite, being more objective;
- Both methods use a stratification approach, though it is applied with different purposes. The EU method uses horizontal stratification to determine similar vegetation communities in large forest fires, while the USA method uses vertical stratification to define the different vegetation layers in a vegetation community.

- The plot layout from the European method is more objective to apply than the one from the USA, although USA method has as a worthy point related to plot layout which considers the disposition of plots for each severity level assessed, enabling the adjustment of the results provided from the satellite data, on the other hand, although stated that this method can also be used in absence of remote sensing, it shows that without it, it would probably lead to lesser conclusive results than the European method.
- The methods studied use different classifications to assess fire severity, ranking from 0 to 4 in EU method and 0 to 3 in USA method. Although different authors consider different fire severity rankings, the one that seems more consensual and common is the rank used in USA method, being 0 - Unburned, 1 - Light, 2 - Moderate and 3 -High. So this method can be related and compared to a higher number of different studies and methods.
-The USA method appears to be more effective, less costly, and also more sustainable, as it aims to obtain the most effective and objective normalized burn ratio by using remote sensing together with local assessment. In the future, this will enable the single use of remote detection to assess fire severity objectively without the necessity to dispend resources to assess severity locally.
However, in absence of remote sensing, the EU method seems to be the most conclusive, because it is more extensive and objective for local assessment, and although it is more timely costly, it obtains a larger amount of data, which can be crossed with other studies.

In relation to the analyzed case studies it is possible to conclude that the achieved results corroborate not only with the ideas put forward throughout the review developed in this paper, but also with the conclusions obtained in similar studies [1, 6 and 18].

Additionally, the completed analysis highlighted that there is an increasing need to evaluate the efficiency of the identified postfire rehabilitation measures, since their effectiveness varies greatly according to the characteristics of the landscapes in which they are applied.

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