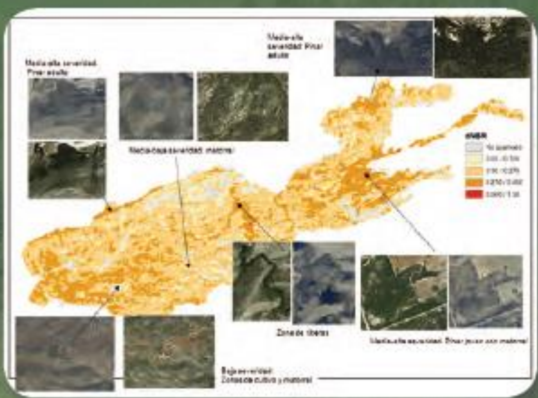
Technical Guide for Burned Forest Management

Action protocols for the restoration of burned areas at risk of desertification



GOBIERNO DE ESPAÑA
MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE

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Action protocols for the restoration of burned areas at risk of desertification

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Madrid, 2013

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Fontúrbel and Cristina Fernández from CIF Lourizán; Tarsy Carballas, Montserrat Diaz Raviña, Serafín González Prieto and Ángela Martín from IIAG- CSIC; Agustín Merino, Mercedes Casal and Otilia Reyes from the Universidad de Santiago de Compostela; Elena Benito from the Universidad de Vigo; Agustín Blond from the Government of the Autonomous Community of Galicia.

TABLE OF CONTENTS

INTRODUCTION

■ RATIONALE

Spain is the European country most at risk of desertification. The Annual Action Plan against Desertification (PAND; 2008), in Spanish *Programa de Acción Nacional contra la Desertificación*, prepared in compliance with the United Nations Convention to Combat Desertification (UNCCD; 1994), points out that forest fires are one of the major causes of desertification in the Mediterranean area where our country is located. Forest fires constitute an intense desertification mechanism, which has major traumatic effects on society as they can turn a naturally high in value landscape into a devastated, desert-like area in only a few minutes.

Figure I-1. The effects of forest fires can give rise to new erosion processes, but it can also accelerate processes developed prior to, and independently of, the fire.

Luckily, Mediterranean vegetation is highly adaptable and resilient[1] to fire, although this is not always enough for it to fully regenerate; it is sometimes necessary to intervene to ensure that the burned area is restored. Indeed, this requirement is set forth in Article 50 (Chapter 3) of the Forestry Act[2], which sets out the need to ensure the necessary conditions for the restoration of vegetation in burned forest lands.

This guide is addressed to professionals holding positions of responsibility in burned forest management. It aims to support technical decision-making leading to the assessment, monitoring and restoration of the affected areas. For this purpose, the guide intends to become a benchmark, a rigorous, adaptable and functioning tool that prioritises restoration activities

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[1] Resilience: A system's capacity to return to its original state after being subjected to stress. Resistance: An ecosystem's inertia facing a change. (As per *The DELFI Vocabulary of Forest Fire Terms).*

[2] Forestry Act 2003. Act 43/2003, of 21 November, on Forestry http://www.boe.es/boe/dias/2003/11/22/pdfs/ A41422-41442.pdf. Act 10/2006, of 28 April, amending Act 43/2003, of 21 December, on Forestry: http://www.boe.es/boe/dias/2006/04/29/pdfs/A16830-16839.pdf

according to damage, their relevance and urgency. All of this is to be carried out according to the principle of saving resources and maximum exploitation of the natural regeneration capacities of each land, in each situation and forest stand. Furthermore, this guide aims to pave the way forward in order to establish an integrated decision-making system for the assessment and monitoring of forest fire impact and restoration actions, which could eventually help establish technical regulations.

For its preparation, use has been made of the knowledge, experience and projects (see references) gathered for over 20 years by technical experts and scientists, mainly Spanish but also from other countries, particularly within the Mediterranean area, as proven by the specific references provided.

The ecological impact of fire depends on many factors (fire regime, vegetation affected, topography, prior uses of soil and post-fire meteorology). The wide variety of factors hinders the assessment of fire impact and the selection of efficient restoration techniques for the wide range of soils within the Spanish territory. On the other hand, forest management requires fast decision-making on the need to act and on the most appropriate techniques in each case. Said actions are also conditioned by our capacity to predict the recovery of burned forests and by the foreseen management goals (Vallejo et al., 2009; Moreira et al., 2012).

In recent years, new initiatives, strategies and protocols for the management of burned areas have been developed at a regional level (Vega et al., 2013a), national level —such as the presentations given during the Wildland Fire Conference in 2007 (Vallejo et al 2007; Vega 2007; Copano 2007) or others (FBS, 2008; Gimeno et al., 2009; Vallejo et al., 2009; de las Heras 2013) and at an international level (Napper, 2006; Lutes, 2006; Pike & Ussery, 2006; Stella et al., 2007, ForFireS, 2008; Robichaud & Ashmun, 2012; Moreira et al., 2012; COST Action FP0701[3]). Nonetheless, these initiatives have not brought about the development of a general application tool that can be used when managing burned areas in the Mediterranean.

To fill these gaps, this project has developed action procedures and recommendations aimed to minimise the negative impact of fires and the rehabilitation of burned areas. The procedures are flexible enough,to be applied in different environmental and management conditions.

This guide has been specifically intended for its application, providing several levels of resolution,based on aims and on available information. As an example, the methods described are applied to an actual fire and provided along with this document (see Addendum I).

Even though this guide is oriented to Mediterranean environmental conditions, the analytical framework it develops is valid for other biogeographical areas in Spain. As explained further on in this guide, its use in other areas requires adaptation to the conditions in each region. Differences in the fire regime, humidity conditions soil saturation, a predominance of resprouting species with capacity to quickly cover the ground and, in general, greater erodibility are some of the distinctive features of forest areas in the Northern areas of Spain compared to Mediterranean areas. These features condition the assessment of variables to be taken into account during the impact assessment as well as calculating an adequate timings for subsequent assessments and actions to be performed.

In order to analyse the applicability of this Guide, a workshop was held with the technical experts from seven Autonomous Communities. The vast experience gathered in post-fire restoration by the experts attending the workshop depicted the administrative, technical, economic and social problems of restoration in all of the geographical areas represented by the experts. In spite of regional differences, it was confirmed that approaches are adopted upon the same technical foundations, which are set forth in this Guide on a systematised basis.

[3] http://uaeco.biol.uoa.gr/cost/

As a result of the presentations and discussions, a general consensus was reached by attendees on the usefulness of a rigorous, flexible and available Technical Guide. It allows guided restoration and for actions to be justified before society, to avoid unnecessary controversy, and establishes priority actions, all of which to be carried out in the current circumstances of budget shortfall.

With regard to economic restraints, the work group also agreed about the difficulty of finding funds to restore small-sized fires (low-profile fires), for restoration in the medium and long terms (in addition to initial budgets set forth in emergency decrees) and the monitoring of the results of actions.

■ Conceptual Framework

Forest restoration actions in burned areas must be planned based on the ecological impact caused by the fire and on forest management goals (Vallejo et al., 2009; Moreira et al., 2012). The analysis and assessment of this impact (and its associated risks) can be approached from several technical, spatial and time-related perspectives. For this purpose, a standardised planning framework and a set of predefined objectives is required (Figure I-2).

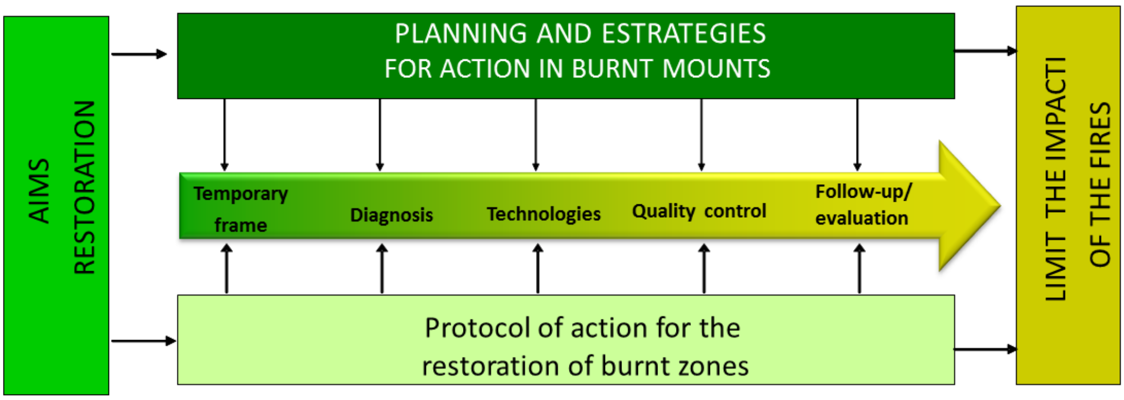


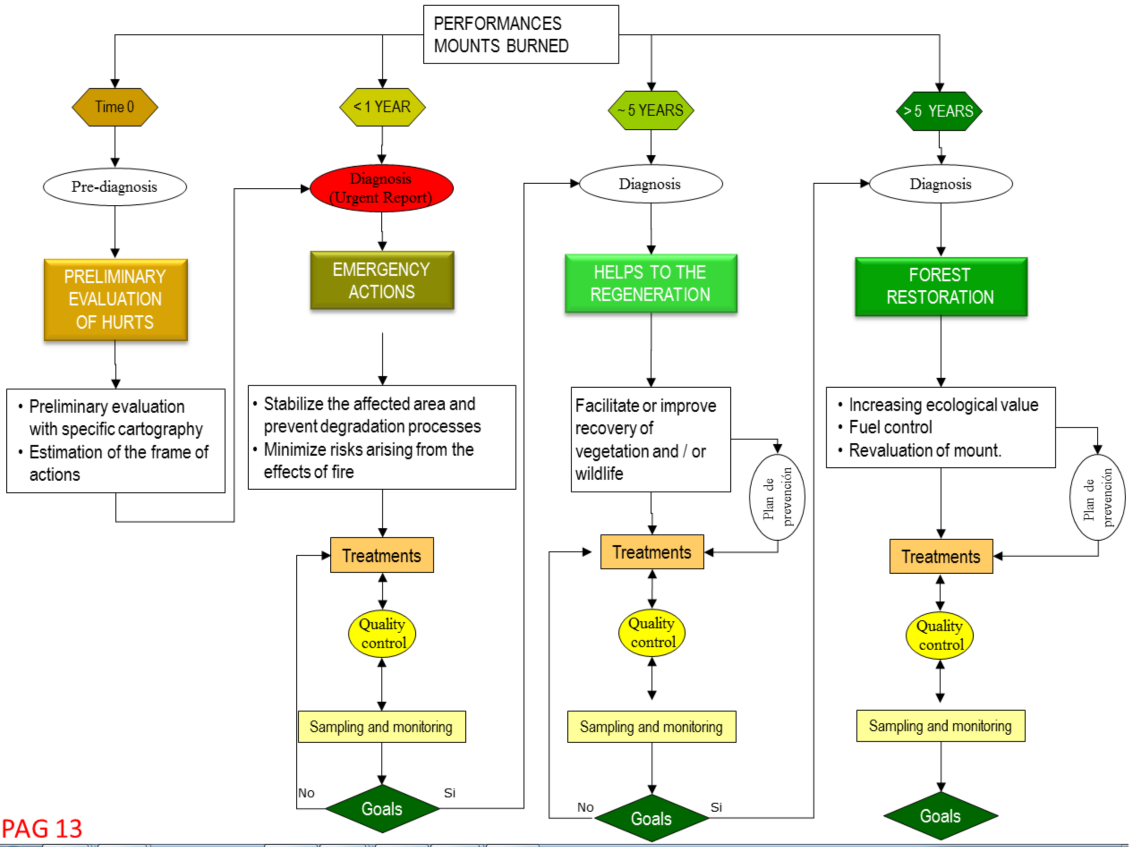
Figure I-2. The proposal aims to standardise the procedures needed to soften the impact of fires. Procedures must be initiated by clearly establishing the objectives expected from restoration.

Forestry planning requires fast assessments and estimations of fire impact upon forest ecosystems and, eventually, the fast triggering of mitigation and rehabilitation/restoration actions[4]. For this response to be efficient, the forestry manager needs maximum information as quickly as possible about the area involved and the features of the fire. Based on the analysis and interpretation of said information, the most adequate restoration options for each situation at risk of soil degradation must be found.

The formulation and selection of restoration alternatives in burned areas can emulate an adaptive management process. This process can be planned in different time frames until the

[4] In the field of ecological restoration, a difference is frequently made between restoration and rehabilitation (Vallejo, 1999). Restoration refers to the recovery of the original ecosystem prior to disturbance (it can adapt to prospective vegetation). Rehabilitation refers to the attempt at recovering an ecosystem that is functionally equivalent to the original one, although with a different specific composition. This would be the case, for example, of the recovery of pine forests within holm oak forests. When performing post-fire restoration, both options can be acceptable depending on management goals and the conditions of the forest affected. This is why, for the sake of clarity, the term "restoration" will be used in both cases.

global restoration of the affected area is achieved. Procedures or techniques to be implemented will include a diagnosis of the ecosystem involved, choosing of adequate action alternatives as per the diagnosis, quality control, monitoring and assessment of actions (Figure I-3):



PAG 13

Figure I-3. Conceptual framework for burned forest restoration with subsequent action phases.

1.- Preliminary impact assessment. The initial analysis of the ecological impact assessment of a fire can be performed from map information at a planning scale (for example, 1:50,000). Maps can give a preliminary and fast idea of the magnitude of fire impact (preliminary diagnosis) and, depending on such impacts, plan the set of actions required to alleviate them. Also, the assessment may be of interest to offer consistent information on the fire impact in the short term, when most demanded by the media.

2.- Emergency actions. Map information (pre-diagnosis) matched with field visits to burned areas can help identify on-site fire impact. The subsequent collection and assessment of data is carried out in a standardised manner, based on a specific protocol. During this phase, the most vulnerable areas are identified and, when necessary, the most urgent actions are proposed to stabilise the affected area and to prevent risks.

3.- Regeneration support. Having completed the first risk prevention phase, the management goal is to ensure the recovery of vegetation cover and predominant species.

In the short term, based on monitoring samplings carried out to check the effectiveness of emergency actions, information can be collected to carry out a diagnosis on level of vegetation recovery, both in terms of cover and composition. Said diagnosis will allow the evaluation of its resilience and forestry quality of the area. If this diagnosis should detect the need to increase resilience, repopulation actions will be designed. In other cases, the necessary techniques will involve selective clearing works to reduce intraspecific competition (it helps regeneration) and reduce fuel loads.

4.- Forest restoration in the medium and long term. The goal is to guide the ecosystem toward self-sustaining mature formations, the composition of which allows to recover the forest value. In this phase, the diagnosis must reflect the environmental status of the ecosystem and the level of fuel accumulation. Actions must aim to enhance forest maturity, its landscape and economic value, to reduce fire risks by controlling accumulated fuel and consider the potential implications of climate change forecasts whilst doing so.

In this guide, methods and criteria are provided to make decisions regarding fire impact assessment. The procedures and criteria included herein constitute recommendations or guidelines to which technical experts in charge of their application can apply different degrees of resolution and, above all, adapt to the socio-economic, environmental and technical conditions of any place. This flexibility is necessary to allow technical experts to use the guidelines as well as their own experience, but does not prevent actions from being carried out under standardised guidelines, allowing for the diagnosis and analysis of potential alternatives.

Figure I-4. The restoration of burned areas must be planned based on the fire impact and response capacity of the ecosystem involved.

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List of the main research projects since 1991 comparing the techniques and experiences explained in this guide:

- Forest fires under climate, social and economic changes in Europe, the Mediterranean and other fire-affected areas of the world (FUME); European Commission, 20102013.
- Prevention and Restoration Actions to Combat Desertification. An Integrated Assessment (PRACTICE); European Commission, 2009-2012.
- Post-Fire Forest Management in Southern Europe (COST-FP0701); European Science Foundation, 2008-2012.
- Climate change and impact research: The Mediterranean Environment (CIRCE). European Commission, 2007-2010.
- Euro-Mediterranean Wildland Fire Laboratory (EUFIRELAB); European Commission, 2003-2006.
- Restoration actions to combat desertificaron in the northern Mediterranean (REACTION); European Commission, 2003-2005.
- Forest fire spread prevention and mitigation (SPREAD); Comisión Europea, 20022004.
- Geomatics in the assessment and sustainable management of Mediterranean rangelands (GEORANGE); European Commission, 2001-2003.
- Restoration of degraded ecosystems in Mediterranean Regions (REDMED); European Commission, 1998-2001.
- Land use change interactions with fire in Mediterranean landscapes (LUCIFER). European Commission, 1996-2000.
- Reclamation of mediterranean ecosystems affected by wildfires (REMECOS); Comisión Europea, 1994-1995.
- Multidisciplinary Research Consortium on Gradual and Abrupt Climate Changes and their Impacts on the Environment (GRACCIE). Plan Nacional de I+D+i CONSOLIDER
- INGENIO 2010, 2007-21012.
- Vulnerabilidad de la Cuenca Mediterránea al Cambio Global. Estrategias de respuesta: Adaptación, Mitigación y Restauración (FEEDBACKS); Plan Valenciano de I+D+i
- PROMETEO, 2009-2013.
- Plan de restauración de la Cubierta Vegetal en la Comunidad Valenciana (Generalitat Valenciana). 1991-2003.

TECHNICAL GUIDE TO THE PRELIMINARY ASSESSMENT OF WILDFIRE ECOLOGICAL IMPACT

■ INTRODUCTION

This methodology has been designed as a support tool for forest planning. It aims to provide a preliminary approach to the post-fire regeneration capacity of forest vegetation in a fast, simplified manner based on the best cartography available. Its application will enable the identification of areas that are potentially more vulnerable to forest fires, which are factors that play an important role in forest planning and management. Identification and spatial location of these zones will enable prevention efforts to be concentrated and, in case of a fire, the tasks involving the assessment of degradation risks.

In order to meet the demand for applicable information systems in the analysis, planning and control of forest resources, the CEAM Foundation has developed a preliminary methodology to assess the impact of forest fires based on cartography and ecological criteria (Alloza & Vallejo, 2005; Alloza et al., 2006; Alloza & Vallejo, 2006; Duguy et al., 2012). The method assesses the regeneration of vegetation based on the potential or intrinsic recovery capacity (self-succession) of the affected plant communities, based on regeneration speed or the time required to recover a protective vegetation cover. Alongside the vegetation potential regeneration, environmental risks are also taken into consideration, estimated by the information provided by soil erosion risk maps (Figure II-1).

Within the framework of this guide, the assessment methodology has been reviused, updated and, most importantly, adapted to the new cartographies available so it can be used in a protocolled format.

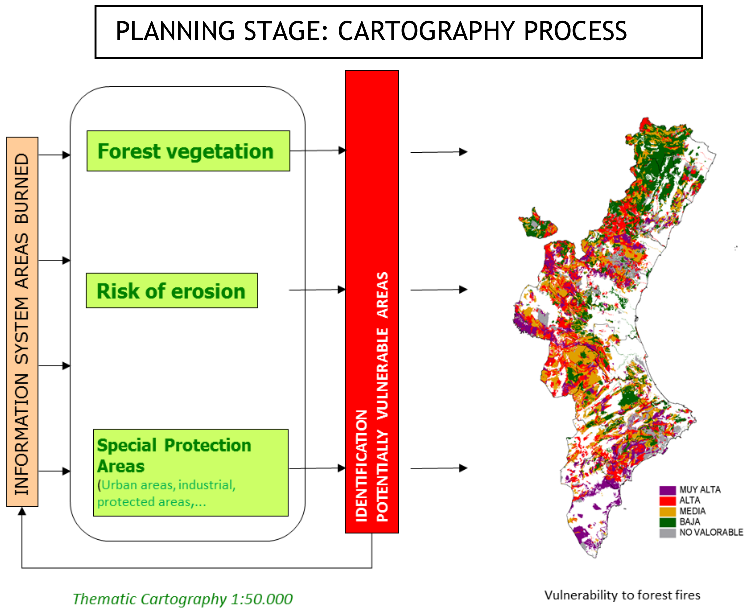


Figure II-1. Cartography process scheme, developed in order to evaluate the early ecological impact of fires using the Autonomous Community of Valencia as an example.

■ CARTOGRAPHIC NEEDS

The guide is focused towards its application with the most up to date thematic cartography. More precisely, the criteria and designations proposed are based on the information available on the digital cartography included in the Forestry Map of Spain (MFE) and on cartography about erosion (National Soil Erosion Inventory -INES- and the Map of Erosion States -MEE). In any case, the methodology is enough flexible to be able to incorporate new criteria or assignments and able to be adapted in each case to available cartography and possible updates.

Vegetation

In digital thematic cartography, there is a lack of up to date information about scrubland structure, the lack of which has limited the development of assessment methodologies with regard to the impact fires have on forest vegetation. Even though scrubland takes up more than 18 million hectares in Spain (San Miguel et al., 2008), in most thematic cartographies nowadays scrubs are characterised in a generic way with the term *"Scrubland"*, without information provided about its structure or other attributes.

Until recently, the only exception was the Forestry Map of Spain on a 1:200,000 scale (Ruiz de La Torre, 1990), henceforth, MFE200. The digital version is available on a 1:50,000 scale and indicates the size and specific composition of the squares taken up by scrubland (Chart III-1). In spite of its age (field works commenced in 1986), it is a benchmark for understanding the distribution of Spanish forest vegetation.

Chart II-1. Structure and contents of the digital forestry map of Spain. Scale 1:200,000 (MFE200). http://www.magrama.gob.es/es/biodiversidad/servicios/banco-datos-naturaleza/informacion-disponible/mfe200_descargas.aspx).

DESIGNATION	DEFINITION
Grid square number	Numerical code for internal purposes
Climate type	The structural bioclimatic type indicates the type of climate that matches the large group of mature vegetation structures, differentiated by their adaptation and/or inclination to greater or lesser humidity/dryness, cold/heat and elevated/low areas. The above, with regard to zonal types. However, in intrazonal types, vegetation is influenced by factors other than climate. There are 19 different types within MFE200: 6 zonal types in the Iberian Peninsula and the Balearic Islands, 5 zonal types in the Canary Islands and 8 intrazonal types.
Developmental level	It is used to rate the relative position of a real type of cover, ranging between completely barren and a theoretical stable situation of maximum adaptation to environmental conditions, maximum use of natural potential and maximum stability as a result of the adaptation of components to cohabitation.
Name of species	Name of species or formation. Four main possible formations are considered (X = 1 to 4). Details on composition, distribution and plant cover presentation mode are provided for each of them
Cover of species on sign	It indicates the cover in tenths of tree species on the sign as designated in the relevant SIGNX.
Mode of presentation	It details the different forms in which arboreal vegetation is described in the related SIGNX field.
Mode of presentation	It details, if a repopulating species, the type of integration in the environment of the species described in the related SIGNX.
Species distribution	It details the type of distribution or evolution of species and/or groups detailed in the related SIGNX field.
Current structure	It details the type of current vegetation structure using a hatch pattern system that can indicate: 1-The ligneous or herbaceous corm structures of the dominant species or group of species and the size of uppermost dominant strata or groups. 2-Special distribution types of tree species. 3-Special types of strata taking up under 15% of the grid square. The grid square may not have any hatch pattern (vegetation with a size of more than 7 metres, agricultural areas without any trees, etc.)
Undersoil	The three most representative species of the undersoil of tree or shrub covers are listed
Companion species	The three companion species or the species making up mixed covers representative of the grid square are listed
Other species	The three species whose presence is of sufficient interest to be mentioned are listed
Inclusions	Three species in enclaves and forest stands that are not visible on this scale and therefore not included in the grid square definition are listed
Galleries and thalwegs	Three species or groupings present in galleries, thalwegs and ravine forests that are not visible on this scale are listed
Species of interest	The presence of species which, although scarce, are interesting enough to be mentioned
Total vegetation cover	It specifies the percentage of total vegetation over the square grid surface
Cover of existing arboreal species	It specifies the global cover of tree species existing in the square grid

The new version of the forestry map on a 1:25,000 scale (MFE25) also contains specific information about scrubs: composition, canopy cover fraction and height (Figure II-2).

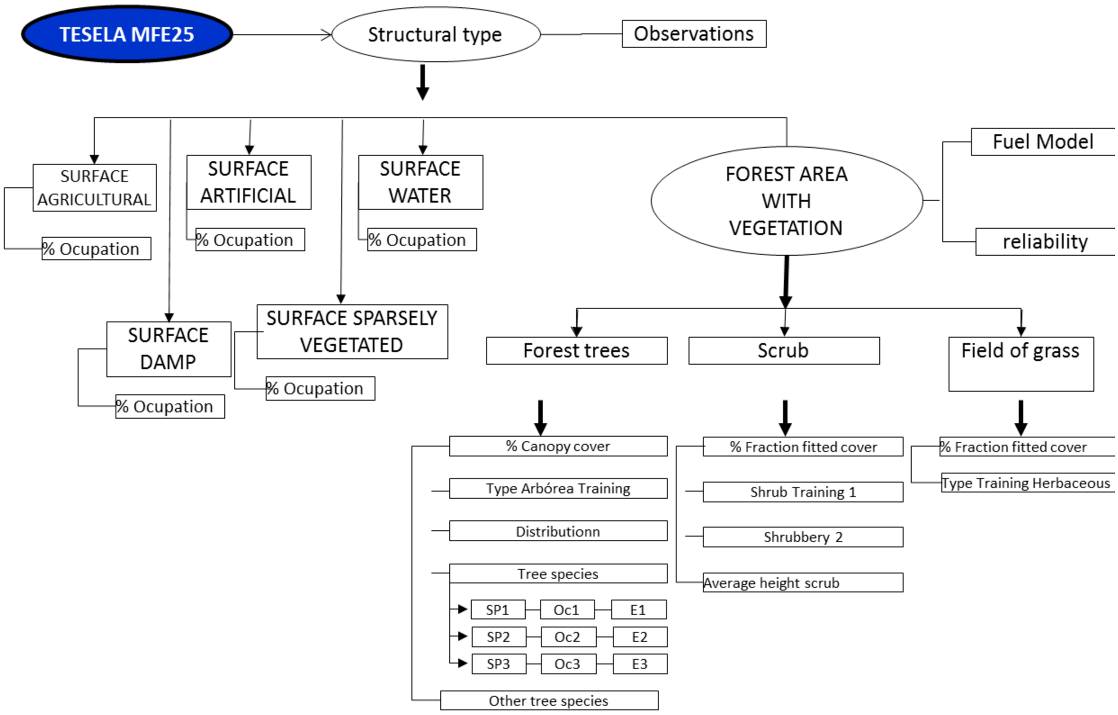


Figure II-2: Conceptual model of forestry map 1:25,000. Taken from http://www.magrama.gob.es/es/biodiversidad/temas/ecosistemas-y-conectividad/mapa-fores-tal-de-espana/metodologia_mfe_25.aspx.

Both MFE200 and MFE25 are available on the Nature Data Bank (BDN) by the MAGRAMA[5].

The criteria developed in this assessment can be applied to both versions of the forestry map:

With version 1:25,000, the following information is required: number of polygon (attribute to related spatial and theme-specific information); fraction of tree canopy cover; tree formation; for each of the main tree species: species code, occupancy and state; fraction of shrub canopy cover; shrub formation, second shrub formation; fraction of grass cover; grass formation.

With version 1:200,000: piece number; developmental level; name of species and cover of species on sign (for all four main species); current structures; total vegetation cover; cover of existing tree species.

Erosion

The most complete digital map information on erosion processes of Spanish soils is that of the National Inventory of Soil Erosion[6] (INES). These maps allow information to be obtained about laminar and rill erosion risks based on current vegetation and potential erosion (without taking into account the vegetation cover), at a working scale of 1:50,000. The erosion

[5] http://www.magrama.gob.es/es/biodiversidad/servicios/banco-datos-naturaleza/default.aspx

[6] http://www.magrama.gob.es/es/biodiversidad/temas/inventarios-nacionales/inventario-nacional-de-erosion-de-suelos/default.aspx

measurement has been performed as a result of the application of the RUSLE model (Revised Universal Soil Loss Equation), which is widely used in the estimation of losses due to erosion in soils affected by forest fires, even though the resulting values can be overestimated (Fernández et al., 2010).

In any case, the information provided by potential erosion cartography allows carrying out estimations of the probability of erosion processes being triggered jointly by relief, climate and soil features. Understandably, the development of erosion processes will be highly dependent on the precipitation (quantity and distribution) that falls after the fire.

Alternatively, in the areas where this cartography is unavailable, local cartography or laminar and rill erosion estimations are available on the Map of Erosion States (MEE). This cartography, drafted between 1987 and 2002, is available for all large river basins on a 1:400,000 scale. As MFE cartography, digital thematic INES and MFE cartography is available in the Nature Databank (BDN) of the MAGRAMA.

■ Application criteria

The methodology assumes, as a general criteria and for potentiality purposes, that post-fire forest vegetation undergoes a self-succession process (Trabaud, 1994). This general principle is conditioned by the fire regime and the reproductive strategy of the affected species. In regard to the latter, an assessment is proposed based on the *intrinsic self-succession capacity* (capacity to reproduce after the fire according to the species' adaptation to fire and its reproductive maturity) and the *speed of regeneration* (response time or time required to cover the floor). In general terms, the following criteria are applied using the cartography available (Figure II-3):

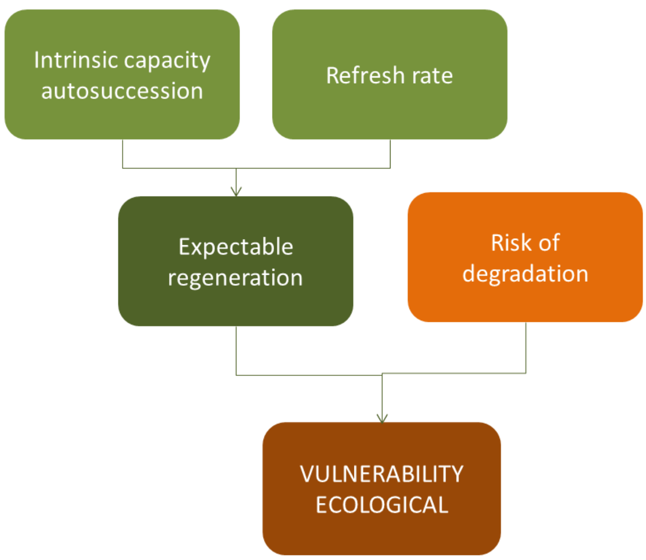


Figure II-3. Criteria used in cartographic assessment of the potential vulnerability to forest fires.

Intrinsic self-succession capacity

Three qualitative categories are proposed:

• **Good:** general criteria applied to all grid squares taken up by shrubs. This category is also applied to all grid squares taken up by trees where there are no pine trees as main arboreal species. In this case, grid squares occupied exclusively (as arboreal species) by Aleppo pines or maritime pines[7] are considered to have good self-succession capacity if in pole or old-growth development stages (this being the minimum threshold required to ensure the reproductive capacity of the stand).

• **Average:** grid squares whose only arboreal species is Aleppo pines or maritime pines in shrub-sapling stages. In these stages, there is no guarantee that the tree will reach the reproductive maturity required to ensure forest regeneration.

• **Low:** any other case where the only arboreal species is pine trees. These cases include mainly grid squares with very young Aleppo pines or maritime pines, or those taken up by black pines, whose post-fire regeneration is problematic (Castell-nou & Martínez, 2002), as well as Scots pines and stone pines (Retana et al., 2012) and Spanish juniper woodlands.

• **Non-quantifiable:** grid squares that, as a result of the lack of information, cannot be assessed.

Figure II-4. Black pines present a low post-fire regeneration capacity (seeds are unable to endure high temperatures, seed dispersal takes place before the time of year most prone to forest fires, alternate bearing,...). Nonetheless, adult samples have a thick bark which enables them to adapt to surface fires. In the picture there is an old-growth black pine stand affected by a surface fire (Sierra del Turmell, Castellón; Fule et al., 2008)

[7] The regeneration of the maritime pine (also known as cluster pine) depends on the quantity of serotinous cones, which varies widely from one location to another (Gil et al., 2009; Fernández et al., 2009).

Regeneration speed

The range of reproductive strategy (germinating or resprouting) in plant species brings about significant differences in the response speed immediately after the fire (Vallejo & Alloza, 1998). The evaluation of each square is established based on the surface percentage taken up by resprouting species, since these cover the ground shortly after the fire. According to the available cartography information, the existing categories are:

- **High:** presence of at least 40% of resprouting species on the square surface; vegetation ground protection is considered to be effective from 30-40% covers (Thornes, 1995). In light of this requirement, a fast response by vegetation (presence of resprouting species and minimum threshold of ground cover correspondingly), rapid protection from erosion is ensured.
- **Average:** presence of 40-10% of resprouting species (or a non-stated percentage) or with mixed strategy species (resprouting/germinating).
- **Low:** presence of fewer than 10% of resprouting species or exclusive presence of germinating species.
- **Non-assessable:** squares that, as a result of the lack of information, cannot be assessed.

Expected regeneration

Intrinsic self-succession capacity and regeneration speed are integrated in one single variable that summarises the potential regeneration capacity or expected regeneration. Integration can be carried out by means of a qualitative assessment (Chart II-2) to obtain an estimation of this regeneration potential on a planning scale.

Chart II-2. Integration of information about the speed of regeneration and the intrinsic self-succession capacity.

<table>
<tr><th colspan="2"></th><th colspan="4">SPEED OF REGENERATION</th></tr>
<tr><th colspan="2"></th><th>*High*</th><th>*Average*</th><th>*Low*</th><th>*No data*</th></tr>
<tr><td rowspan="3">INTRINSIC SELF-SUCCESSION CAPACITY</td><td>*Good*</td><td>Good</td><td>Average</td><td>Low</td><td rowspan="4">N/A</td></tr>
<tr><td>*Average*</td><td>Good</td><td>Average</td><td>Low</td></tr>
<tr><td>*None*</td><td>Low</td><td>Low</td><td>Low</td></tr>
<tr><td></td><td>*No data*</td><td colspan="3">N/A</td></tr>
</table>

Using the above criteria, an initial approach to assess expected plant post-fire regeneration is available. However, there are many other factors that can condition how vegetation responds: fire features (intensity/severity, time of year, etc.), precipitation after the fire and soil types in the affected area. Fire features are hard to predict. However, the effect of physical factors can be summarised on the soil's risk of degradation which can result from the erosion risk.

Degradation risk

Regeneration capacity depends on the features of the physical environment. In this regard, the risk of degradation arising of the soil loss due to erosion is highly relevant.To measure this risk, a re-classification of INES cartography on potential soil erosion is proposed, giving place to the following categories: low risk, 1 to 25 t/ha/year; medium risk, 25 to 50 t/ha/year; high risk, 50 to 100 t/ha/year and very high risk for >100 t/ha/year.

The estimation of degradation risk can be supported with climate-specific data, such as an estimation of the intensity of the dry period (Alloza & Vallejo, 2006). However, this information is not always available.

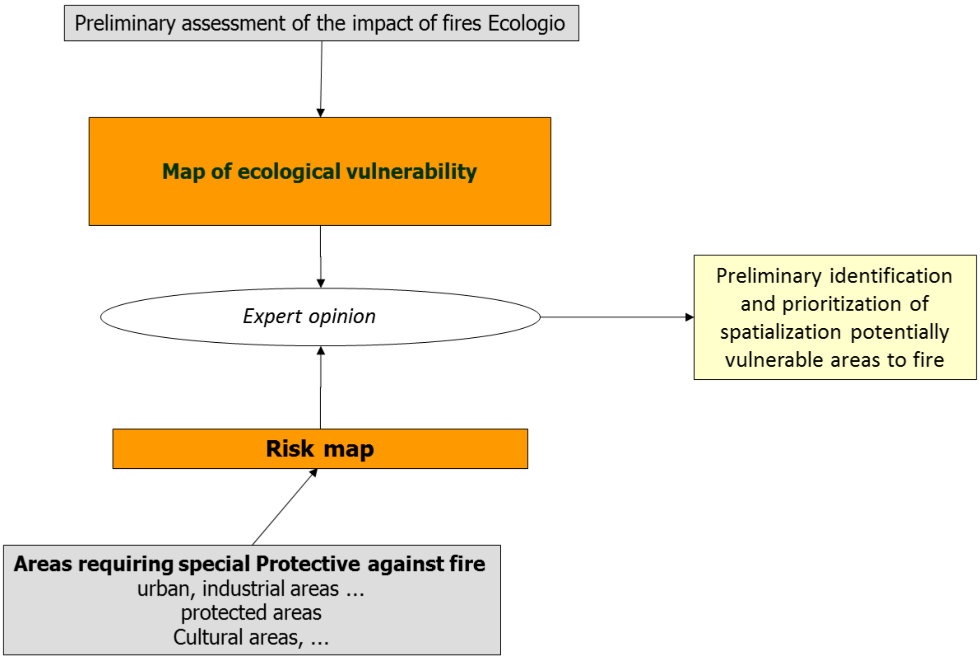
Potential vulnerability

The integration of cartographies with information about expected regeneration and the risk of degradation (Chart II-3) enables the identification of the areas that potentially are the most vulnerable to forest fires (areas with lower regeneration capacities and greater risks of soil degradation).

Chart II-3. Integration of expected regeneration and risk of erosion to determine the potential vulnerability to forest fires.

		Potential erosion (t/ha/year)			
		Low (<=25)	*Average (25-50)*	*High (50-100)*	*Very high (>100)*
Regeneration	*High*	Low	Average	High	High
	Average	Average	Average	High	Very high
	Low	High	High	Very high	Very high

The estimation of potential vulnerability can be slightly altered through the application of other criteria (urban areas, protected areas, highly valuable cultural sites, areas near water streams with a greater risk of downstream sediment transport). The integration of this information (by means of expert opinions setting forth the particularities) will give rise to cartography where the areas that are potentially more vulnerable can be identified and marked up, therefore enabling the concentration of management actions in the future (Figure



II-5).

Figure II-5. Integration of ecological criteria and other risks to identify, on a planning scale, the most vulnerable areas to forest fires.

Based on good-quality cartographic information about foreseeable fire severity that is available (assessed as per "design fires"; Castellnou et al., 2009), this stage can also provide an emergency diagnosis of the impact of a fire, although verification through field inspections will be needed in all cases.

■ Application procedures

In this guide, we have standardised an assessment procedure that uses the most detailed and up to date forest vegetation cartography, in our case the Forestry Map of Spain on a 1:25,000 scale. Balance between the criteria used has been sought so as to ensure rigorous forecasts using a simple application that can be applied to all forest map sheets available. Since not all map sheets at a 1:25,000 scale are included, reference is also made to the application using the 1:200,000 Forestry Map version.

Application using the 1:25,000 forestry map

On the cartographic version, the alphanumeric data of the Forestry Map are encoded. The file detailing spatial distribution of grid squares and alphanumeric information is included into a database to apply assessment criteria on a standardised manner. The procedures to follow must be the following (Figure II-6):

1.- Importing the forestry map file containing the alphanumeric data (dbf format). This file will allow keeping thematic assignments and spatial or cartographic distribution.

2.- For an adequate interpretation of the specific composition, type of formation, etc., literals are assigned to numeric fields. The literals used are those described on the Forestry Map metadata (data dictionary).

3.- Each square identifies existing species (up to three arboreal species, up to two scrub formations and the herbaceous layer). Each of the species is assigned with their reproductive strategy (the predominant or more characteristic one in the case of shrub or grassland formations).

The reproductive strategy of all the species included has been assigned on the forest map. The information used in the assignments is based on publications (Pausas & Paula, 2005; Paula & Pausas, 2009) and individual experiences and databases. Addendum 2 sets forth the "Assignment of dominant reproductive strategies in vegetation species and formations in the 1:25,000 forestry map".

4.- The total canopy cover fraction taken up by arboreal resprouting species, scrubs and grasslands is obtained. In arboreal species, the canopy cover fraction taken up by serotinous species in pole or old-growth development stages (such as Aleppo pines and maritime pines) is also taken into consideration and aggregated. Finally, the total and stratum-disaggregated coverage by resprouting species is also worked up: arboreal (including serotinous species with reproductive capacity), shrubs and pastures.

5.- The assignment of assessment criteria is conducted according to the speed of regeneration and the self-succession capacity:

a.- Regeneration speed: if the total canopy cover fraction taken up by resprouting species is >=40%, high regeneration speed is assigned; capacity is deemed to be average if the canopy cover fraction taken up by resprouting species stands between 10% and 40%, while it is considered low when resprouters are under 10%.

b.- Self-succession capacity. Depending on the type of plant formation. High self-succession capacity is assigned to squares taken up by grasslands, shrubs or trees with resprouting or adult serotinous species. On the contrary, low self-succession capacity is assigned to squares taken up by black pines and to grids occupied by very young Aleppo or maritime pines.

6.- Re-encoding of the map of erosion states. Erosion categories are re-encoded as per the potential erosion intervals described above.

7.- Overlapping, assignment of criteria and obtaining of maps: GIS procedures applying the criteria in Charts II-2 and II-3 (Figure II-6).

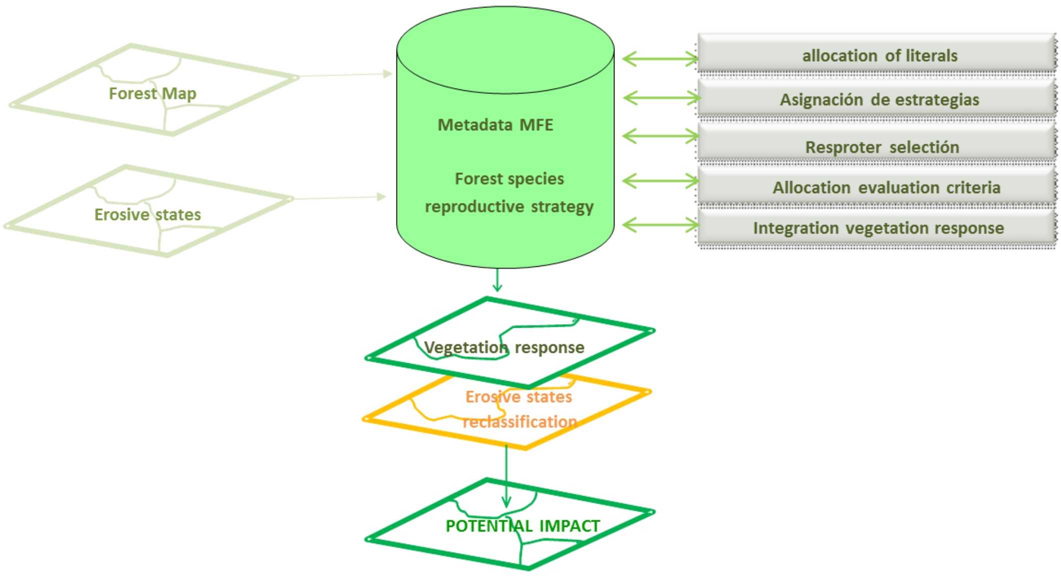


Figure II-6. Cartographic information, forest maps and cartography on soil erosion are processed within a GIS environment where reproductive strategies are assigned (the total canopy cover fraction occupied by resprouters is calculated), as well as re-classifications and overlaps.

Application using the 1:200,000 forestry map

The procedure is very similar to that described above. As in the 1:25,000 version, a prior process of assignment of literals (based on official metadata) and reproductive strategies to the species existing in each square is required.

In the assignment of reproductive strategies, a maximum the four main species that each grid square contains are taken into consideration. Even though there are other fields within cartography associated with the presence of species (companion species, unusual species, gallery species...), these fields do not always contain information and their relevance in spatial terms is limited.

Another representative feature of this version has to do with the age of pine forest masses. From the information available, we can only calculate the approximate age based on height. As a result, taking into consideration the height intervals used in cartography, pine forests are deemed to be have full reproductive maturity when they exceed 3 m, whereas intermediate maturity is believed to range from 3 to 1.5 m and no reproductive capacity (the trees are not known to have reached reproductive maturity) is attributed when under 1.5 m. Assessment and integration criteria are identical to those described above.

■ Application Example

Three application examples are provided: in Galicia and Murcia, using the 1:25,000 Forestry Map of Spain (MFE25) and the Autonomous Community of Valencia using the 1:200,000 Forestry Map of Spain (MFE200). Addendum I shows an example of the assessment of a burned area.

1:25,000 Forestry Map of Spain (MFE25)

The application of the methodology has been performed in two clearly differentiated geographical areas: Galicia and Murcia[8]. The main results obtained from the application of the methodology are set forth in Figures II-7 and 10 and Charts II-4 and 6.

Chart II-4. Percentage of qualitative categories of regeneration capacity in forest surfaces in Murcia and Galicia.

Regeneration capacity	%Murcia	%Galicia
HIGH	53.2	83.6
MEDIUM	17.4	2.1
LOW	29.5	14.3

In Galicia, resprouting species prevail in forest areas, which enables the estimation of an adequate regeneration capacity of over 80% of the surface. On the contrary, the regeneration potential in Murcia is lower owing to a greater presence of germinating species and young-growth pine forests.

Chart II-5. Percentage of categories of potential erosion risk in forest surfaces in Murcia and Galicia.

Category (t/ha/year)	% Murcia	% Galicia
<= 25	8.8	7.5
25-50	6.9	6.9
50-100	12.5	10.5
>100	71.8	75.2

As per the cartography included in the National Soil Erosion Inventory, areas with high or very high erosion risks prevail across the forest surfaces of both Murcia and Galicia (Charts II-5 and II-7). In both cases, over 70% of the forest area presents high or very high risks (including soil loss risk exceeding 200 t/ha/year).

Based on the proposed methodology, the potential vulnerability to fires is calculated based on the comparison of potential erosion and regeneration potential cartography. Results suggest that high or very high values of potential vulnerability to fire prevail in both cases, although extreme cases (very high vulnerability) are more common in Murcia (Chart II-6; Figure II-10).

Chart II-6. Distribution of categories of potential vulnerability to fires in forest areas in Murcia and Galicia.

	%Murcia	%Galicia
Low	3.9	5.5
Average	6.1	7.9
High	53.0	74.4
Very high	36.3	11.5
Non-assessable	0.7	0.7

[8] The cartography of the forestry map 1:25,000 of Galicia and Murcia, along with the relevant cartography of the National Soil Erosion Inventory has been provided by the Nature Data Bank Division (Ministry of Agriculture, Food and the Environment)

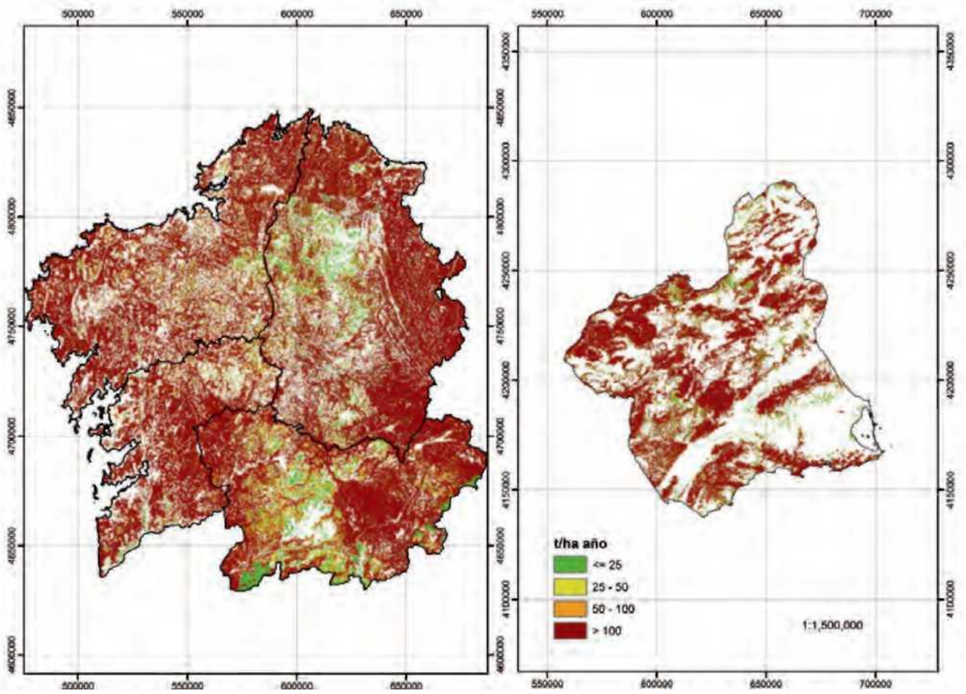


Figure II-7. Distribution of potential erosion categories in grid squares of forests in Galicia and Murcia. Key: Green: under 25 t/ha*year (Tonnes/hectares per year). Yellow: 25-50 t/ha*y. Orange: 50-100 t/ha*y. Red: over 100 t/ha*y.

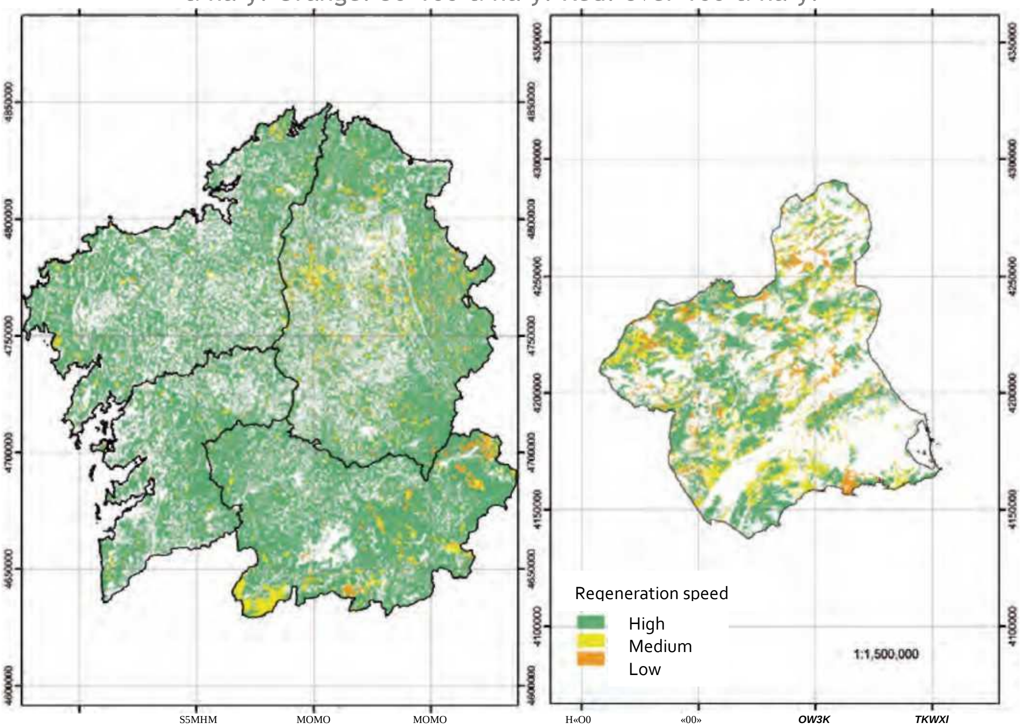


Figure II-8. Distribution of categories of regeneration speed assigned to grid squares of forests in Galicia and Murcia. Key: Green: high. Yellow: medium. Orange: low.

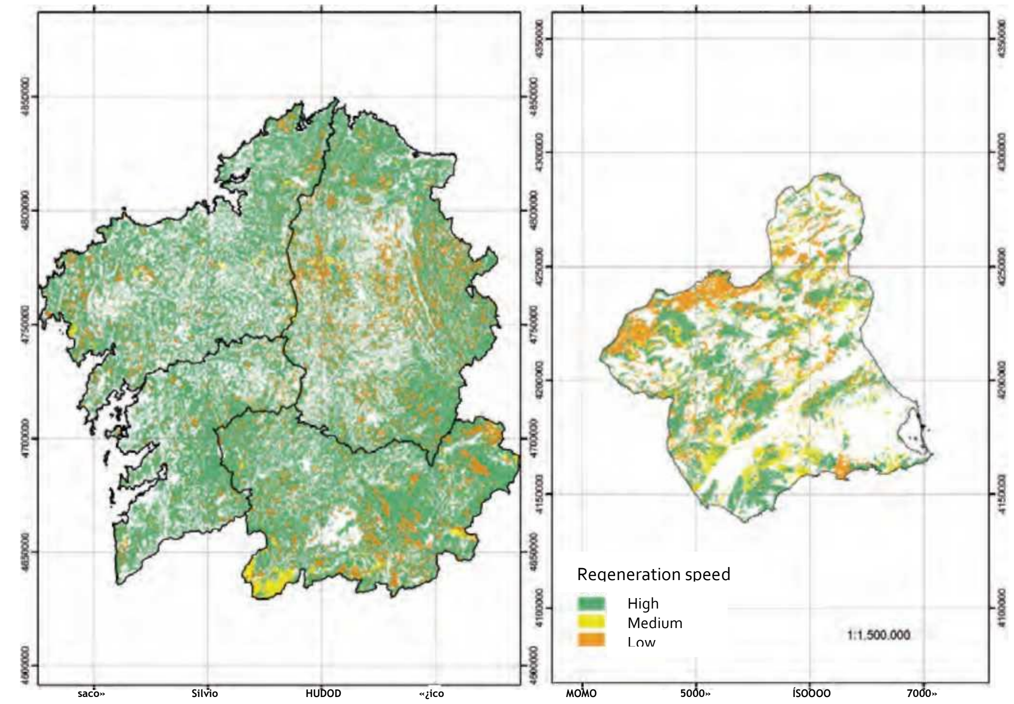


Figure II-9. Distribution of categories of intrinsic self-succession capacity (regeneration capacity) assigned to grid squares of forests in Galicia and Murcia. Key: Green: high. Yellow: medium. Orange: low.

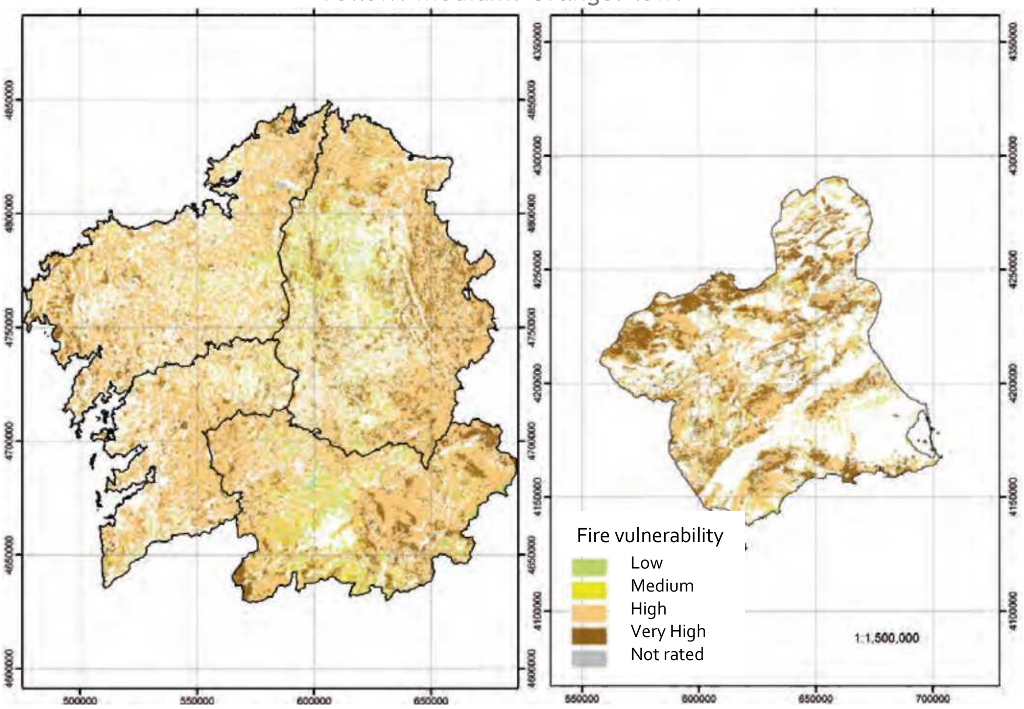


Figure II-10. Distribution of categories of potential vulnerability to fires in forest areas in Galicia and Murcia. Key: Green: low. Yellow: medium. Light ochre: high. Brown: Very high. Grey: non-assessable.

1:200,000 Forestry Map of Spain (MFE200)

As indicated, the cartography provided in the 1:25,000 Forestry Map of Spain and the National Soil Erosion Inventory is not available for all regions, which is why an example of the application of this methodology using the 1:200,000 Forestry Map of Spain (MFE200) is provided, in this case applied to the forest surface of the Autonomous Community of Valencia.

Using the digital cartography of the 1:200,000 Forestry Map of Spain, the assessment is carried out using the information provided in the hatch pattern, size and main species fields (up to four species per square).

Results suggest that the total forest surface of Valencia has a high self-succession potential (intrinsic self-succession capacity; Figure II-11), meaning that a fire would not cause significant changes in the affected plant communities[9]. As per the speed of regeneration, over 70% of the forest surface is expected to have a fast response to a forest fire and therefore the ground is expected to be covered quickly. The integration of both factors (Figure II-11) suggests an acceptable regeneration capacity of over 60% of the surface, the regeneration speed being the main conditioning factor.

The limitations imposed by the physical environment have been estimated based on the maps on degradation risk (Alloza & Vallejo, 2006) obtained from the intense dry period (bioclimatic intensity) and erosion risk. In regard to this cartography, 37% of the forest surface in Valencia is at a high or very high risk of degradation.

By adding the regeneration capacity and the degradation risk, it is suggested that the forest surface has a high or very high potential vulnerability to fire in 38% of the forest surface of Valencia (Figures 11-12).

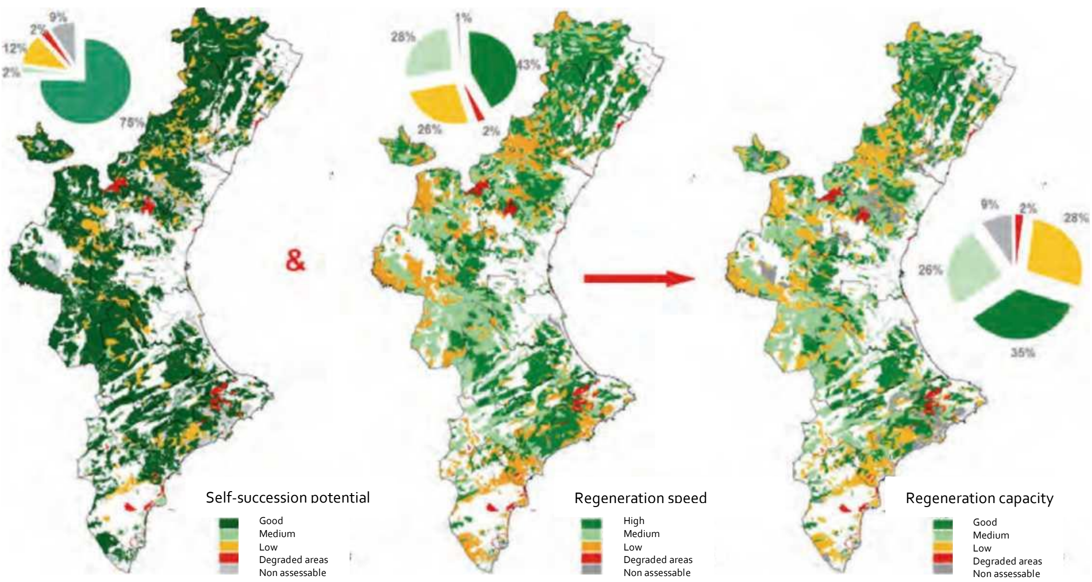


Figure II-11. Distribution of the categories of intrinsic self-succession capacity (self-succession potential) in the Autonomous Community of Valencia (left) and regeneration speed (middle) obtained from the digital version of the 1:200,000 Forestry Map of Spain. The regeneration capacity (right) is worked out by overlaying the other two maps and applying the criteria in Charts II-2. Key: Dark green: high. Light green: medium. Orange: low. Red: degraded areas. Grey: non-assessable.

[9] Since the information included in this cartography is quite old, it does not depict the possible changes undergone as a result of the fires that have taken place since the 90s in the Autonomous Community of Valencia (over 300,000 ha).

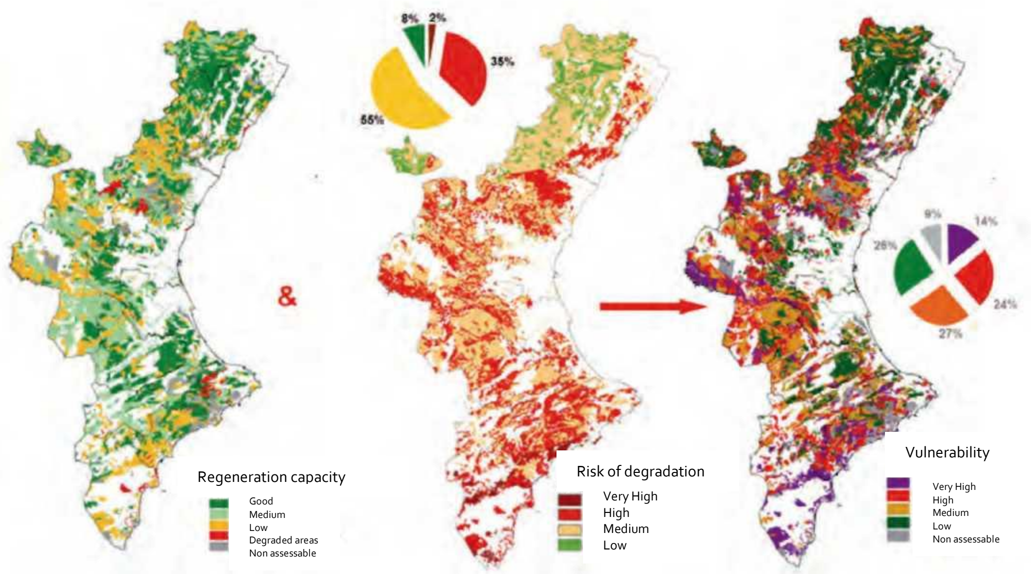


Figure II-12. Image on the right: Distribution of the potential vulnerability categories in the Autonomous Community of Valencia. (Key: Purple: very high. Red: high. Orange: medium. Green: low. Grey: non-assessable). The map is the result of overlaying the regeneration capacity map (image on the left obtained from Figure II-11 above) and the degradation risk map (image in the middle; Key: Maroon: very high. Red: high. Orange: medium. Green: low). This degradation map is obtained by overlaying soil erosion and intensity of the dry period cartographic information (Alloza & Vallejo, 2006). The criteria applied in overlaying are as described in Chart II-3.

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TECHNICAL GUIDE TO THE EMERGENCY ASSESSMENT OF FOREST FIRE ECOLOGICAL IMPACT. INSPECTION OF THE AREA AND RECOMMENDATIONS

■ INTRODUCTION

The effect of fire on soil and vegetation increases the risk of water erosion (Scott et al., 2009; Shakesby, 2011), therefore during the years immediately following a fire, erosion processes can be triggered within the most vulnerable zones.

This guide intends to specify recommendations in order to analyse, in a systematic and practical way, the ecological impact of forest fires, to obtain a global vision of the affected area and aid decision making when trying to manage burned areas (Figure III-1).

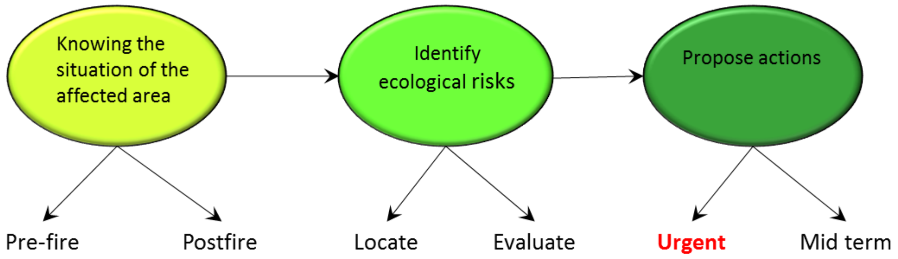

Figure III- 1. The guide develops support procedures to aid decision making when managing burned areas.

This guide is focused towards Mediterranean environmental conditions, although its application can be extended to the Atlantic region. The differences in climate, soil and vegetation characteristics, as well as in fire regime between the biogeographical regions of the Atlantic and Mediterranean involve considering the assessed variables in different ways. Some of the most notable differences are:

- Whilst in the Mediterranean region it is necessary to carefully study the presence, or lack of resprouting species in order to assess the strength of vegetation response after a fire, this approach has less relevance in the Atlantic region, as the Atlantic climate is dominated by resprouting species, such as gorse *(Ulex europaeus),* whose regrowth and germination is encouraged by fire (Reyes & Casal, 2008).
- The severity of fire on soil tends to have more relevance when assessing the impact of fires in the Atlantic region than in Mediterranean conditions. Relevant factors are the typical soil characteristics in the Atlantic region, such as greater contents of leaf litter and organic material from the soil, higher levels of soil moisture during the season more prone to forest fires and mostly sandy textured soil (although these features also can be found in Mediterranean conditions), in which hydrophobicity is a common phenomenon.
- Although in the Mediterranean environment, especially by the coast, torrential rain capable of causing heavy soil losses is frequent, the probability of post-fire rain is a lot higher in the Atlantic region and therefore is the erosion strength of the climate (Figure III-2).

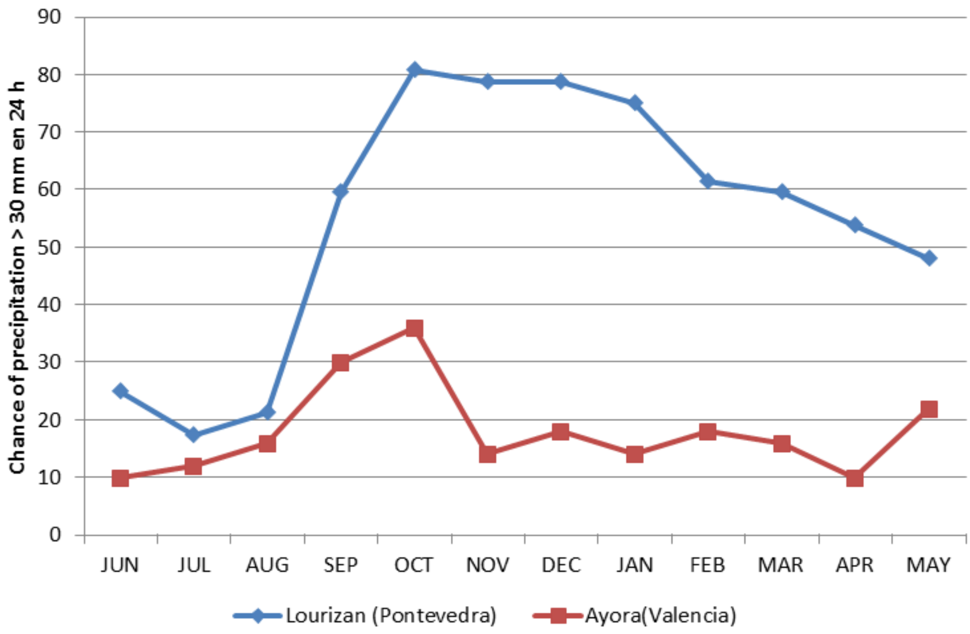

Figure III-2. Monthly breakdown of the maximum likelihood of rainfall in 24 hours, equal or superior to 30 mm, in one station in Pontevedra (time period 1960-2012), and another from the inland area of the province of Valencia (time period 1950-2000). The maximum rainfall in 24 hours ≥ 30mm is related to the erosion strength of the rain (Regional Government of Andalusia, http://www.juntadeandalucia.es/medioambiente).

- Erosion control actions must be carried out as soon as possible after the fire in vulnerable areas. In the Atlantic region, as previously mentioned, there is an elevated risk that after a fire very high erosion rates and sediment movement will be triggered, which frequently affects strategically productive sectors (for example shellfish gathering). This constrains the protocol application deadlines aimed to assess the impact and emergency procedures needed to alleviate the erosion processes. These procedures must carried out immediately after the fire so they have the greatest possible impact; the speed of the vegetation response by covering the ground will minimise the impact by the following season.

In conclusion, the analytic framework that this guide develops is valid for the different biogeographical regions of Spain. It needs to be adapted to the individual conditions of each region in regard to measuring the variables when assessing impact and in order to carry out assessment and procedures on the field.

The methodology has been structured in four phases (Figure III-3): documentation, inspection of the area, impact assessment and recommendations (immediate report on impact).

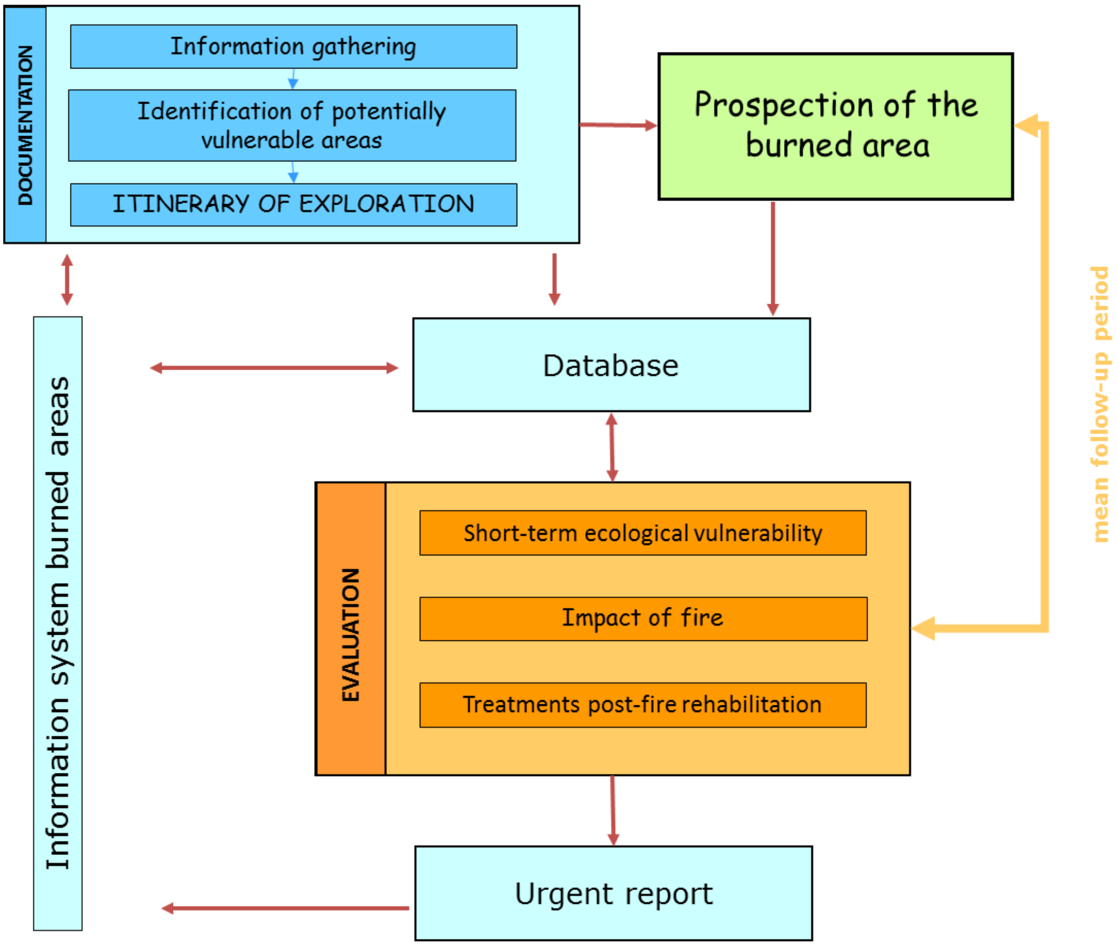

Figure III-3. Work scheme to assess the impact of large forest fires.

The following sections describe the recommended procedures to carry out the assessment process.

■ DOCUMENTATION

During this first stage, all available information (both cartographic and alphanumeric) with regard to the features of the area affected by the fire and the development of the fire is gathered:

1.- Physiography (gradient, direction...), lithology, vegetation, fauna and flora of interest, protected areas, soil uses, traffic roads, etc. in alphanumeric and digital cartographic format (maps, images, remote sensing, ortophotos). The work scale will be conditioned by the available digital cartography and by the size of the fire, ranging from 1:5,000 for ortophotos and detailed topography studies, up to 1:50,000 for lithology or vegetation.

2.- Climatology, meteorology right before and after the fire, rainfall that took place between the fire and inspection of the area.

3.- Fire recurrence, fire perimeter and development.

4.- Other specific documents on the affected area which could be relevant for the purposes of the assessment. In this regard, the information contained in management schemes, fire reports and fire fighting reports can be very helpful. Also, the information about the land plots (and the size thereof) can be helpful to learn about the previous management of the area and the potential obstacles in case of emergency.

In this stage, the goal is to split the burned area into homogeneous environmental units in terms of fire impact and to identify those that are potentially vulnerable (Figure III-4).

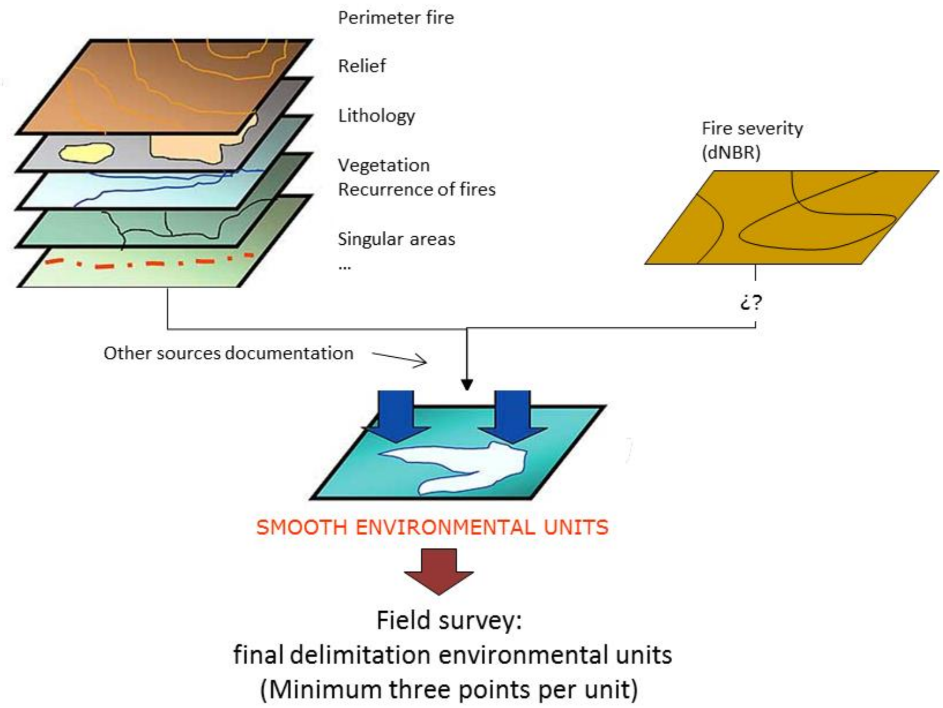

Figure III-4. The division into environmental units is carried out firstly using the cartographic information available and it is adjusted later according to the information obtained during the area inspection.

Environmental units

Environmental units are relatively large areas presenting homogeneous features with regard to their gradient, lithology, vegetation, recurrence and fire severity. Depending of the size of the fire and/or the heterogeneity of the area affected, sub-units can be established. Sub-units are groups of forest stands presenting similar features with regard to dominant plant species, development stages and thickness which can be treated individually if in need of specific post-fire treatment.

Prior division of homogeneous areas contributes to easier area inspection and itinerary design. However, the final division of these units will be carried out as per the information gathered during the inspection. During the documentation stage there is no detailed information about the fire, the extent of the impact on vegetation, signs of previous erosion, composition and structure of vegetation, etc. That is why environmental units and vulnerable areas at this documentation stage will be provisional and subject to review after the inspection phase.

For instance, in relatively homogeneous fires and using the cartography available in the Autonomous Community of Valencia, the provisional environmental units found during the documentation phase fall under the following types:

- Tree area dominated by species with potential post-fire regeneration capacity (basically oak stands and adult Aleppo or maritime pine forests).
- Tree area not expected to recover after the fire (non-serotinous pine forests and young Aleppo or maritime pine forests).
- Scrubland (depending on the cartographic information available, we could differentiate the areas dominated by germinating species and by resprouting species).

In large-sized or highly heterogeneous fires, these categories are combined with relief or lithology features as well as vegetation thickness, differentiating between thick and sparse canopies and shrubs covering over or under 60% approximately.

In any case, the final division of environmental units will be carried out based on the inspection of the area, which can point out the relevance of some variables not taken into consideration in this phase (such as insolation, micro-topography, etc.). In any case, units must be representative of the environmental conditions of the burned area but the amount thereof must be efficient.

Potentially vulnerable areas

The factors taken into consideration to identify potentially vulnerable areas are the response capacity of the affected vegetation and the sensitivity of the soil to water erosion.

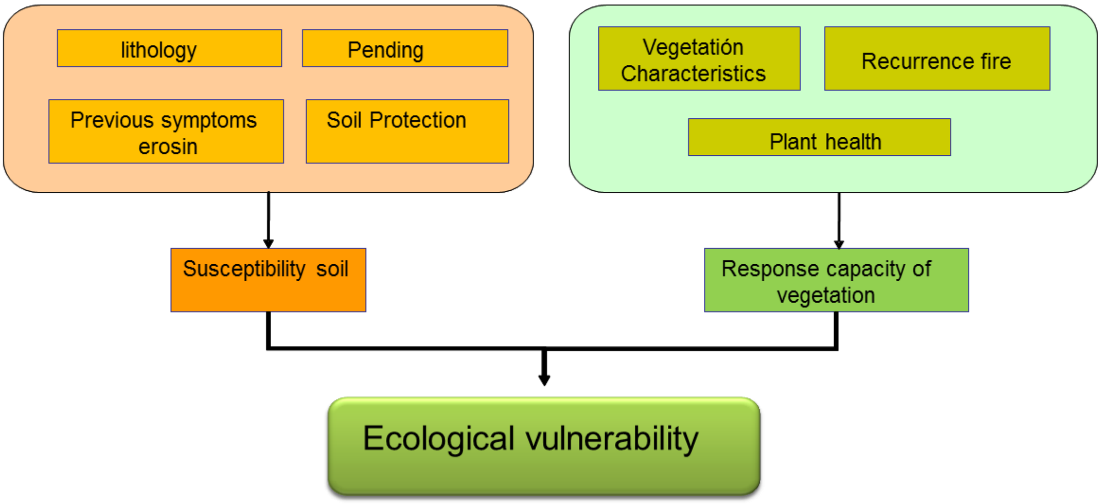

Figure III-5. Diagram used to estimate short-term ecological vulnerability of a stand, integrating soil sensitivity and the response capacity of vegetation.

The recovery capacity of burned vegetation mainly depends on the features of vegetation itself and on fire recurrence. The greater the recurrence, the lower response capacity. As for vegetation features, the slowest response can be expected from formations with the lowest vegetation cover and germinating reproductive strategies which, owing to their young age, have still not reached their reproductive maturity or the capacity to produce abundant viable seeds.

Soil sensitivity to erosion depends mainly on its erodability and gradient. If adequate cartography is not available, erodability can be worked out from lithology details.

Preliminary determination of environmental units will be conducted by overlapping the maps of analysed factors. This task can be performed, when available, using the cartography included in the preliminary assessment.

■ Inspection of the area

Once the preliminary determination of environmental units is completed, the following step is to explore the field. For this purpose, some logistic resources must be prepared:

- Printing of cartography and inventories
- Contact with environmental agents
- Organisation of itineraries and overlapping of sampling grid

The visit to the burned area is conducted a few days after the fire has been extinguished to gather data about the severity of the fire. This information is then completed with that provided by environmental agents (and other relevant social agents) and with photographs of sample plots.

Environmental agents or forest managers are thoroughly familiar with the territory and provide valuable information about the development of the fire, the state of logging roads, plant health condition prior to the fire, erosive events that could have taken place further to the fire, flora and fauna of interest, silviculture treatments and management issues in recent years, etc., while they can confirm or elaborate on any of the cartographic information used in the previous phase.

As a preliminary step, an action that facilitates subsequent inspection tasks is to observe the burned area from spots where you can have a general view of the area. This will allow a preliminary confirmation of environmental units, an early approach to fire severity and sometimes it is the only way to spot areas of difficult access. It also allows pictures to be taken that can be used for georeferencing purposes and support the assessment.

Having gathered the relevant information in previous phases and early data from the burned area, data are then collected from sample plots. Sample spots are selected on a map of the burned area, which is overlain with a polygon mesh, the vertices of which are to be the spots for potential data collection.

The density of the sampling mesh is conditioned to the extension of the fire (Chart) and to the access possibilities (terrain features, density of logging roads), meaning that a greater amount of spots will be necessary the bigger the burned surface is and as the terrain complexity and fire perimeter increase.

Chart III-1. Recommendation for sampling grid density depending on fire extension for areas with poor accessibility. Sampling points will be located upon this theoretical grid with a varying density depending on the situation (between 6 and 15 sampling points are recommended in fires under 500 ha and over 50 points for fires extending over 5,000 ha or more).

Fire area (ha)	100	500	1,000	2,500	5,000	7,500	10,000
No. grid points	50	100	150	300	500	600	650
No. sampling points	6-15		25-50		>50		

The grid serves as a guide to locate possible sampling points. Nonetheless, not all grid points will be subject to sampling (Figure III-6). The urgent nature of the assessment requires data to be collected within a limited period of time. That is why data collection cannot be carried out as a systematic sampling process. As a result, only some of the grid points are subject to sampling, which are selected according to two criteria: accessibility and representativeness. Purposive sampling is carried out, which even though it lacks any probabilistic value, can be more efficient than systematic sampling when there is little time for field work and the study is of an exploratory nature. The grid limits subjectivity in the selection, since it reduces the bias that the user could introduce if points were chosen freely. On the other hand, the user must choose the points that are the most representative of all environmental units.

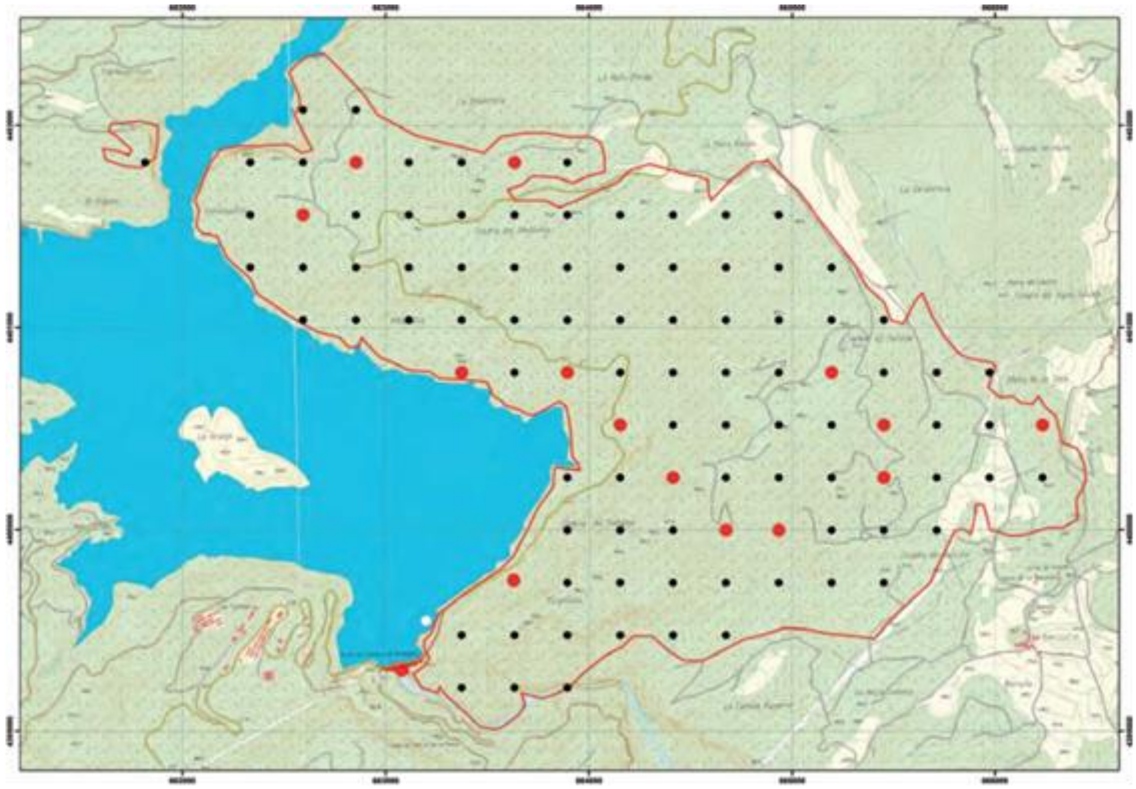

Figure III-6. Perimeter of Chelva-Benageber fire (Valencia) in 2012. Regular grid distribution of theoretical points (in black) and sampling points (in red).

As a consequence of the type of sampling chosen, the number of points in the grid is much larger than the number of points where data are actually collected. On a general basis, it is recommended to follow these criteria with regard to the points to be sampled:

- In each environmental unit/sub-unit, at least three points will be chosen. More points will be chosen in the most vulnerable or particular areas. Should there be particular or highly vulnerable stands (such being areas which, as a result of their small size, are not considered sub-units), one sampling point in each of them will be chosen.
- The number of sampling points per fire should not be under 6 in 100-ha fires, 15 in fires under 500 ha and 50 in fires extending for 5,000 ha or more.

For operational purposes, two types of data collection points are established: Observation Points (OP) and Sampling Points (SP). Observation points are designed for the areas with poor accessibility which hinders direct (on-site) data collection and therefore observation needs to be carried out remotely. On the contrary, sampling points are used to directly collect quantitative data on the area, both with regard to the features of the area and to the severity of fire. Data collection is conducted within a circular area, 20 m in radius, the centre of which will be the SP coordinates.

The following chapter describes the sheets to be filled out for data collection at each point[10]. This information will be used to evaluate erosion risks, the response capacity of vegetation and pest risks. Sheets 1 and 2 are used to collect general data on the fire and the burned area, which can be found in cartography or obtained from forest managers and environmental agents. Sheets 3 and 4 include the data collected at OPs and SPs. Sheets 3 and 4 are filled out at each SP. With regard to OPs, only the sections of sheets 3 and 4 that can be

[10] Inventories available at www.ceam.es/Estadillos_Guia.doc

noticed from a distance must be filled out. The variables in sheets 3 and 4 are organised in the following sections:

- Physiography and lithology.
- Existence of pests, diseases or damage due to abiotic factors.
- Previous symptoms of erosion, terracing, anthropogenic changes on the soil.
- Composition, covering and reproductive strategy of vegetation prior to the fire.
- Severity of fire upon the different vegetation strata and the soil horizon.
- Post-fire soil surface features.

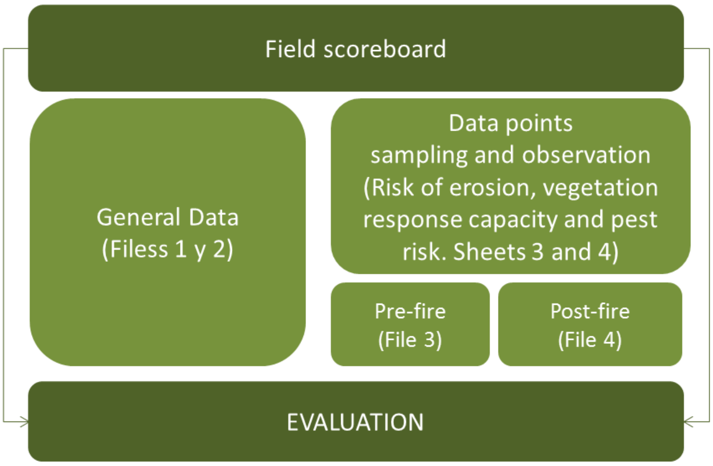

Figure III-7. Diagram of distribution of data on field inventories.

■ Fire Description Sheet

The information about the whole burned area is registered in data sheets, which includes data collected both during the documentation and the field inspection phases (Sheets 1 and 2). In addition to collecting the necessary data, these sheets can be used as questionnaires during the documentation phase to guide the interactions with environmental agents or other agents familiar with the area. The contents of these sheets are listed under the following sections:

A) FIRE

- **Fire code:** if there is no official code, we propose to use the name of the municipality where it originated (max. 8 characters), the month and the year of the fire (in both cases using two digits and no blank spaces between them); for instance, REQUENA0894.
- **Place of origin of the fire:** it is usually that used for the fire name.
- **UTM of outbreak point:** X and Y coordinates in metres.
- **Cause of fire (if known):** arson, negligence, wildfire, reignition of previous fire.
- **Start date and extinction date.**
- **Inspection dates (first and last inspection visits).**

- **Province(s) and municipalities affected by the fire. Area affected in each municipality, according to ownership** (public, communal, private) **and use of its land** (forested areas, unforested areas, non-forest).
- **Urban-forest interface:** specify whether the fire has affected the surroundings of urban areas.

B) CARTOGRAPHY AND PHOTOGRAPHS

- **Topographic cartography:** mark on sheets 1:10,000 and 1:50,000 where the fire outbreak spot is located, as well as on other sheets that include a part of the fire-damaged surface.
- **Ortophotos prior to the fire:** when available, index aerial photographs taken before the fire.
- **Digital cartography:** index the cartographic information available for the affected area: remote sensing, vegetation, lithology, fire recurrence, etc.
- **Photographs of the affected area:** index units and sub-directories where the files containing the photos taken during the field inspection stage are filed.

C) SOCIO-ECONOMIC ASSESSMENT OF THE AREA

- **Educational and recreational value of the area:** indicate whether socio-cultural activities are held in the area. Indicate, where appropriate, where tourist, educational or recreational facilities are located.
- **Cultural value:** indicate the existence of cultural, religious or ethnographic heritage, monumental trees, etc.
- **Exploitation of timber resources:** indicate whether there were timber exploitations before the fire and whether they were sporadic or frequent.
- **Exploitation of non-timber resources:** indicate whether there were any before the fire, which there were, their intensity and ownership (private, communal or free).
- **Hunting:** indicate whether hunting activities were held before the fire and which species were hunted.
- **Grazing:** indicate whether pastures were used before the fire and for which cattle species.
- **Areas of special interest:** indicate the existence of areas subject to protection categories (natural park, municipal natural sites, protected landscapes, microreserves, SCIs, SPABs, Cave Catalogue, etc.). Indicate the area affected by the fire within each protection category. Indicate the presence of remarkable species.
- **Active crops:** indicate the burned agricultural area and the dominant type of crop. If the fire perimeter includes burned agricultural surfaces and others where the crop species has not been burned, estimate the proportion/surface of both separately.
- **Residential areas within the fire perimeter:** indicate their location or UTM as well as their area. If the fire has entered an urban area, estimate the percentage of affected area.

D) METEOROLOGY-CLIMATE

- **Existing meteorological stations:** indicate the stations to be used to profile the area. Within the closest stations, it is recommended to use those with a similar altitude to the burned area and which have a large historical series and data from dates before the fire.
- **Thermoclimate and ombroclimate of affected area:** as per the classification set out by Rivas-Martínez (1987).
- **Synoptic status during the fire:** indicate synoptic status of weather at the time and the maximum temperature and minimum relative humidity during suppression, as well as average and maximum wind speed.
- **Rainfall amount between fire suppression until the sampling date:** indicate registered rainfall between the time the fire was extinguished until the field inspection.

E) FIRE RECURRENCE

- **Percentage of surface that has burned 0, 1, 2 or more times before** in the past 20 years.
- **List of prior fires:** indicate the date and code of the main fires registered in the area in the past.

F) OTHER DETAILS

- **Identified environmental units:** brief description and sampling/observation points within them.
- **Widespread presence of biotic and/or abiotic damage:** indicate whether there was widespread damage on vegetation before the fire and possible causes (biotic and/or abiotic).
- **Existence of pests or diseases near the affected area** that could spread the fire deeper into the fire-damaged area. Indicate the site or the UTM where they are located.
- **Condition of natural drainage network:** especially indicate whether there are risk situations or risks in the surrounding areas or whether there are girdling processes.
- **Presence of infrastructures at potential erosion or flood risk:** indicate whether any infrastructure (reservoir, road, etc.) or urban area can be directly affected by increased erosion of the fire-damaged area.
- **General condition of logging roads:** identify the existence of spots or sections exposed to the risk of triggering erosion processes. More precisely, details will be provided on whether the risk is due to: the presence of neglected gutters presenting minor flow problems; water flow outside the gutter, eroding the pavement with rills; water flow outside the gutter, presenting erosion gullies; clogging in crossing areas or sewers...
- **Presence of flora/fauna/habitats of interest for conservation purposes:** presence of endemic or endangered flora; species and habitats included in the EU Habitats Directive, monumental or remarkable trees, etc.
- **Estimation of the risk of predation of seeds or damages caused by herbivores:** indicate whether the presence of some species (or their density) could compromise natural regeneration, whether as a result of seed predation or of damages to sapling or sprout forests.
- **Presence of seed sources on the edge of the fire/alive trees within the perimeter with recolonisation capacities:** assess whether the presence of non-burned trees within the fire perimeter or on the edge of the burned area can constitute a significant contribution to natural regeneration.

- **Presence of invasive species that could extend after the fire:** indicate whether there are invasive species within the burned area or its proximity.

SHEET 1. FIRE GENERAL DATA

A) Fire

Fire code *(town+2 month digits+2 year digits)* ________________

Place of fire outbreak *(the fire code usually takes after this place)* ________________

<u>Fire outbreak</u>

Outbreak spot (UTM)

Cause of fire

Fire outbreak date

Fire suppression date

Inspection date

Province(s)

Region(s)

<u>Surface affected per municipality. Land ownership and use</u>

Affected municipalities	(ha)		Ownership (%)
		Public	
		Private	
		Others (communal, assoc.,...)	
Total area affected			

Soil use	(ha)
Forested area	
Unforested area	
Non-forest area	

Urban-forest interface Affected Yes/No Town name:

B) CARTOGRAPHY AND PHOTOGRAPHS

<u>Topographic cartography</u>	outbreak spot	remaining area affected
Sheet 1:50,000		
Sheet 1:10,000		

<u>Ortophotos prior to the fire</u>

Location *(folder name)*

<u>Digital cartography</u>

Lithology map

Vegetation map

Other

<u>Photos of affected area (*)</u>

Location *(folder name)*

(*) the folder with photos of the affected area will include a list setting forth the code for each photo, information about its location (UTM or site description and direction toward the photo was taken) and other relevant remarks

SHEET 2. FIRE GENERAL DATA (continued)

C) SOCIO-ECONOMIC ASSESSMENT OF THE AREA

Educational/recreational/cultural value (leisure, sports, tourism, tradition, ethnography, religion, etc.)

Value type	Activity/infrastructure description	Site/UTM

Intensity of exploitation of timber resources **none** **moderate** **high**

Exploitation of other forest resources **mushrooms / aromatic plants / honey / others:** ______

None moderate high **Exploitation ownership:** private / communal / public

Hunting: ____________ **Grazing:** _________________

Areas of special interest (natural park, municipal site, microreserve, SCIs, SPABs, etc.)

Protection category	Site name	Area affected by fire (ha)

Active crops

Total surface within burned area: _____ ha or _________ % out of total

Crop type: dry land _____ irrigated land _____ Main species ____________

Burned crops (ha) Non-burned crops (ha)

Distributed across all burned area Located in one specific area: ______________

Residential areas within the fire perimeter

Location		Total surface (ha)		% areas affected	

D) METEOROLOGY - CLIMATE

Existing stations

Thermoclimate of affected area Ombroclimate of affected area

Circumstances during the fire:

Maximum temperature Minimum temperature

Minimum relative humidity Maximum winds

Rainfall amount between fire suppression until sampling date:

E) FIRE RECURRENCE: SURFACE BURNED BEFORE IN THE PAST 20 YEARS

No. of previous fires	0	1	2	>2
% surface				

List of previous fires (dates and names):

F) OTHER DATA (to be filled out depending on the fire details)

1. Description of identified environmental units (sampling and observation points within each unit):
2. Widespread presence of biotic and/or abiotic damage in sites near the fire:
3. Existence of pests or diseases in the vicinity of the affected area:
4. Condition of natural drainage network:
5. Infrastructures at a potential risk of downstream erosion/flood (swamp, road, town):
6. General condition of logging roads:
7. Flora/fauna/habitats of interest for conservation purposes, monumental trees:
8. Estimation of the risk of predation of seeds or damages caused by herbivores:

■ FIELD INSPECTION INVENTORIES

The variables gathered during the field inspection at each of the sampling or observation points are set out in Sheets 3 and 4. Below is a list of some of their main features:

NUMBER OF OBSERVATION/SAMPLING POINT: numeric code assigned to identify the point. This code must be identical in cartography (sampling grid) and in the database.

NUMBER OF POINTS ASSIGNED AS A RESULT OF SIMILARITY: indicate other points within the grid which, as a result of their similarity, can replicate the information for this point.

A) GENERAL DATA

- **UTMX, UTMY, altitude:** to be filled out with GPS data or at an office. Values in metres regarding datum ETRS89.
- **Predominant relief:** flat, summit, butte, convex hillside, concave hillside, piedmont, glacis, valley/ravine bottom.
- **Dominant orientation:** N, NE, E, SE, S, SW, W, NW, all winds.
- **Dominant gradient:** in percentage (<15%, 15-30%, 30-45%, >45%) or degrees.
- **Forest management actions carried out in the area:** on vegetation (repopulation, silvicultural system, etc.) or on the soil (subsoiling, terraces, etc.). Brief description indicating the approximate date of execution.
- **Evident causes of soil degradation:** If any, indicate whether the agent causing soil degradation has been identified (overgrazing, landslides, runs, etc.).

B) PLANT HEALTH CONDITION. This section approaches the intrinsic plant health risks of the sampling point. It does not contemplate the possibility of pests or diseases extending from other areas up to the sampling point (this has already been considered in the general data sheet).

- **Presence/absence of pests, disease or damage due to abiotic factors:** especially in arboreal or shrub species.
- **Affected plant species.**
- **Agent causing the damage:** name or type (if several species are causing similar damage and the species causing them is unknown).
- **Impact of damage:** low, moderate or high; depending on the percentage of samples affected and the impact upon the affected trees. For example, in the case of bark beetles: (a) minor impact when they are observed in the orifices of isolated trees, without having killed the trees; (b) moderate impact when the bark beetles have caused death in recent years and they have been observed in orifices of many trees; (c) major impact when they have caused the death of many trees.
- **Risk of the pest or disease extending:** insignificant, low, moderate, high; depending on the post-fire state of the area and the biological features of the pest/disease. For instance, in the case of bark beetles, the greatest danger occurs when pine trees have survived the fire but are very weak (a significant part of their crown has been compromised).

C) SOIL STATE BEFORE THE FIRE[11]. This section comprises the variables related with soil features and their erodibility (before the fire).

- **Lithology:** hard limestone, soft limestone, dolomite, marl, gypsum, conglomerates, colluvium (and rock type), river drift (gravel, sand, silt and/or clay), sandstone, argillite, slate, quartzite, granite, schist, gneiss...
- **Soil:** when known, indicate the type as per FAO/UNESCO or USDA Soil Taxonomy classification.
- **Depth:** indicate the predominant features regarding useful depth for root penetration purposes.
- **Effervescence to HCl:** apply 10% hydrochloric acid drops to a sample of the surface mineral horizon and describe the resulting effervescence (none, light or strong). Avoid sampling soil that is in direct contact with fire ash.
- **Average pH value:** taking a sample of the mineral topsoil (0-5 cm) to determine pH in the lab. Taking samples from the soil at each sampling point is not necessary; it will be sufficient to take 1-2 samples for each environmental unit. Avoid sampling soil that is in direct contact with fire ash, since the goal is to obtain a pH value other than that after the fire.
- **Type of erosion/accumulation:** identify the processes existing at the sampling point (laminar erosion, in rills, in gullies, badlands, accumulation, wind erosion, landslides, breakdown of walls, etc.) and their intensity: low, moderate or severe (Figure III-8 and 9). With regard to water erosion, the global value of erosion intensity will be obtained by aggregating the laminar, rill, gully and badland erosion(Chart III-2), which can be carried out at the office once the inspection is over.

[11] To interpret the soil variables and categories, you may check the FAO Guidelines for soil description ftp://ftp.fao.org/docrep/fao/011/a0541s/a0541s00.pdf

Figures III-8. Short-distance dragging of ash, with no erosion effects.

Figure III-9. Signs of erosion in gullies active before the fire.

Chart III-2. Global value of water erosion (global WE) obtained by aggregating the different signs of this kind of erosion

When there are badlands of low, moderate or severe intensity: WE_{global} = extreme

When there are not any badlands, the decision process is as follows:

1) When there is erosion in gullies with severe intensity: WE_{global} = extreme
2) When there is erosion in gullies with moderate intensity: WE_{global} = severe
3) When there is erosion in gullies with low intensity:
    a. If there are rills with moderate or severe intensity: WE_{global} = severe
    b. If there are not any rills or they present low intensity:
        i. If there is severe laminar erosion: WE_{global} = severe
        ii. If there is no laminar erosion or it has low/moderate intensity: WE_{global} =moderate
4) When there are no gullies:
    a. If there are rills with severe intensity: WE_{global} = severe
    b. If there are rills with moderate intensity: WE_{global} = moderate
    c. If there are rills with low intensity:
        i. If laminar erosion presents moderate/severe intensity: WE_{global} = moderate
        ii. If there is no laminar erosion or it has low intensity: WE_{global} = low
    d. If there are no rills
        i. If Laminar = severe --> WE_{global} = moderate
        ii. If Laminar = low or moderate --> WE_{global} = low
        iii. If Laminar = none --> WE_{global} = none

- **Existence of terraces:** non-existent, few or widespread (taking up more than 1/3 of the plot). If they do exist, indicate whether in terraces (a) agricultural tasks are still being carried out, (b) agricultural tasks have been interrupted recently so spontaneous vegetation is still dominated by weeds or ruderal species, or (c) forest vegetation is already dominant.

- **State of terraces.** Indicate the state of conservation of walls or embankments in the terraces: (a) they are well conserved; (b) there are a few degradation processes going on: breakdown of walls, landslides, piping, etc.; (c) there are widespread degradation processes (Figure III-10).

Figure III-10. Sampling point with abundant terraces, colonised (before the fire) by forest vegetation and presenting widespread breakdowns.

D) PRE-FIRE VEGETATION. In this section, information is gathered aimed to predict the response of vegetation after the fire. In this regard, resprouting and serotinous species are given more importance owing to their greater potential and regeneration speed. Cover intervals used are supported by the fact that covers under 30-40% are not sufficient to reduce water erosion, while there are no erosion problems when over 60%.

1. TREES

- **CCF:** canopy cover fraction, in percentages (<20%, 20-40%, 40-60%, 60-80%, >80%).
- **Distribution of trees:** uniform, isolated trees, trees and shrubs/grassland mosaic, adult tree and tree regeneration mosaic.
- **Name of existing species, occupancy of each of them (before the fire) and state of development of the forest.** Indicate the abundance of each species (relative abundance, in respect to the appearance of the bush layer, rating in from 0 to 10). Indicate natural age class (Chart III-3) for each species (for masses with a structure that tends to be regular). As for structures that tend to be irregular, indicate the percentage of trees with a size that is similar to each of the natural age classes.
- **Forest origin:** natural (or with no evidence of reafforestation), planting or seeding.
- **Serotinous species:** indicate the abundance of cones/fruits on the crown layer of the forest. Serotinous species react well to fire as long as they have reached their reproductive maturity. In this regard, the *P. halepensis* is the species that raises most doubts, since during the shrub-sapling phase the production of pine cones varies significantly. In this case, forests in sapling phase are considered to have abundant pine cones if there are more than 10 pine cones on each tree, which ensures the existence of certain amount of serotinous pine cones.

Chart III-3. Description of natural age classes in thick regular forests

Natural age class	Description
Scattered/Reforested	Until tree crowns start to be tangent
Sapling phase	Until the start of natural pruning of branches that remain in the shadows.
Pole phase	Until standard diameter reaches 20 cm
Old-growth	Diameter over 20 cm

2. SCRUBS

- **Total scrub cover:** estimate the soil percentage covered by scrubs before the fire (excluding widespread rock outcrop areas).
- **The most abundant species** before the fire and the space each of them took up. It is not necessary to identify all scrub species, but only those which prevailed within the soil cover prior to the fire. For the purpose of recognising the scrub species in severe fires, there is only large woody debris, which as a result requires some specific training.
- **Floor covering with resprouting species:** estimate the percentage of soil that the resprouting scrub used to cover before the fire (excluding areas of widespread rocky outcrops).

3. HERBACEOUS STRATUM

- **Total herbaceous cover:** estimate the soil percentage covered by herbaceous species before the fire (excluding widespread rock outcrop areas).
- **The most abundant species** before the fire and the space each of them took up. It is not necessary to identify all herbaceous species, but only those which provided significant soil cover prior to the fire. Recognising the species and estimating the herbaceous cover can be impossible in some very severe fires. Sometimes it is impossible to deduce the species based on unburned vegetation patches in the surrounding area.
- **Floor covering with resprouting species:** estimate the percentage of soil that the resprouting herbaceous species used to cover before the fire (excluding areas of widespread rock outcrops).

4. FUEL MODEL.

- Indicate the fuel model of vegetation prior to the fire, as per the ICONA classification (MAP 1987, Chart III-4). There is an updated version in Rodríguez & Molina (2010).

Chart III-4. Fuel models (MAP, 1987)

Group	Model	Description
Pastures	1	Fine, dry and low pasture that fully covers the ground. There can be some woody species taking up under 1/3 of the surface.
	2	Fine, dry and low pasture that fully covers the ground. Woody species cover 1/3 to 2/3 of the surface, but spreading of fire occurs through the pasture on the ground.
	3	Thick, dense, dry and high pasture (over 1 m). Typical of savannah and swamp areas with mild-hot climates. Cereal fields.
Scrubs	4	Scrubs or very dense young stands, of over 2 metres of height with dead branches within. Fire spread through the crowns.
	5	Thick and green scrubs, under 1 m of height. Fire spreading through leaf litter and pasture.
	6	Similar to model 5, but with more inflammable species or tree-felling debris or plants of bigger sizes.
	7	Scrubs of very inflammable species, between 0.5 and 2 m of height, in the form of underbrush areas in coniferous forests.
Leaf litter under the canopy	8	Thick forest, no scrubs. Fire spreads through very compact leaf litter. For example, thick forests of wild pine trees or beech.
	9	Similar to model 8, but with less compact leaf litter made up by long, rigid pine needles or foliage of hardwood plants with large-sized leaves. For example, *Pinus pinaster*, chestnut trees or *Quercus pyrenaica* forests.
	10	Forest with large amounts of wood and fallen trees as a consequence of strong winds, intense pests, etc.
Debris of pruning and silvicultural activities	11	Open or heavily thinned forest. Scattered debris of pruning or thinning with resprouting herbaceous plants.
	12	Predominant debris on tree crowns. Pruning or thinning debris covering the ground.
	13	Large accumulation of thick and heavy debris covering the ground.

E) POST-FIRE VEGETATION STATUS. The goal in this section is to assess the severity of the fire upon vegetation.

1. TREES

Severity: for each existing tree species, indicate the severity of fire impact (Chart III-5, Figures 11 and 12). If the severity in the plot was heterogeneous, indicate the percentage of trees that were affected by each level of severity.

Figure III-11. Pine forest with scattered burned and unburned areas, with low, moderate and high severity.

Figure III-12. Burned pine forest, very severe.

Are there any pine nuts on the ground? Serotinous species show remarkable seed dispersal capacity during the days after a fire. Indicate the abundance of seeds observed. Winged pine nuts can be considered an indicator. Slightly shaking the tree can help verify this phenomenon. The amount of pine nuts is considered abundant when estimated that under normal conditions it could generate a fully thick forest. For example, for *P. halepensis,* 1 pine nut for every m^{-2} would be abundant, but not 1 pine nut for every 5 m^{-2}, as it is expected that approximately 2,000 trees ha^{-1} reaching sapling age would be needed to have a CCF over 70-80%.

Chart III-5. Levels of severity of impact on trees

Severity	Description
Low	The trunk base is slightly scorched but the crown remains green.
Average	The trunk is partially scorched. Part of the crown has been scorched or burned, but over 50% remains green.
Severe	The crown has been mainly scorched (as a result of the radiating surface fire) so over 50% of the crown keeps dry leaves on branches. These leaves can be lying on the floor if the inspection is conducted several weeks after the fire. In some cases, a part of the crown can remain green. In other cases, the leaves in a part of the crown can be burned.
Very severe	The crown has been affected mainly by combustion (crown fire), so the leaves have been completely consumed by fire. Less than 50% of the crown has dry leaves on branches.

2. SCRUBS

Severity: indicate the severity of fire impact (Chart III-6, Figures III-13 and 14). If severity in the plot varies, indicate only the dominant level of severity.

Figure III-13. Burned gorse in a severe fire.

Figure III-14. Kermes oak scrubland burned in very severe fire.

Chart III-6. Levels of severity of impact on scrubs

Severity	Description
Low	Over 50% of scrubs remain unaffected or present large green areas
Medium	Over 50% has been affected, even though there are some plants with green areas
High	The whole scrubland has burned (no green leaves) but some twig ends remain unburned
Very high	Completely scorched (only the thickest branches, approximately >6 mm, remain standing)

3. HERBACEOUS STRATUM

Severity: indicate the severity of fire impact (Chart III-7, Figure 15). If severity in the plot is heterogeneous, indicate only the dominant level of severity.

Chart III-7. Levels of severity of impact on herbaceous stratum

Severity	Description
Low	Quite a few green areas remain after the fire
Medium	Herbaceous species have been scorched or burned but the structure of leaves is still recognisable.
High	Herbaceous species have been consumed by fire.

Figure III-15. Grass clump burned, medium severity.

F) POST-FIRE SOIL STATUS. The goal of this section is to assess the severity of the fire upon the soil and the post-fire water erosion risk. This information must be reported immediately after the fire since the percentage of bare ground clearly changes rapidly throughout the weeks and months after the fire. On a general basis, the year after a fire is the period when burned areas are most vulnerable to water erosion and assessment is required of whether the existing plant or stone cover is capable of efficiently protecting the ground.

- **Bare soil.** Indicate the percentage of soil that has been left bare after the fire, without any vegetation, leaf litter or stone cover (ash is not deemed to protect the floor, so it counts as bare soil). The part of the plot taken up by rocky outcrops is excluded from this calculation (Figure III-16).

Figure III-16. Floor with abundant surface stoniness.

- **Rock fragments.** Indicate the percentage of soil covered by surface stoniness (excluding rocky outcrops).
- **Rocky outcrops.** Indicate the level of occurrence of rock outcrops: non-existent, exceptional (taking up under 5% of the surface), frequent (between 5 and 40% of the surface) or widespread (taking up over 40% of the surface).
- **Rate of soil crusting.** Considerable according to the soil crust thickness and consistency when dry: light crusts tend to be less than 2 mm thick and break easily, the moderate ones tend to be 2-5 mm and the severe ones tend to be more than 5 mm and are very hard. Hills with severe crusting are a source of run-off water.
- **Significant presence of continuous biological crust.** Indicate if there is a common or widespread presence of lichens, cyanobacteria, algae, moss etc. covering the soil. If these organisms only appear occasionally, it is not necessary to register their presence.

Soil horizons

Affected leaf litter. Indicate the impact of fire to the leaf litter horizon covering the floor if there is one: (a) at least a part of the litter has remained intact, (b) scorched, burned or partially consumed litter prevails, (c) most of the leaf litter has been burned down to ashes (Figures III-17).

Figures III-17. On the top, scorched leaf litter (partially affected); on the bottom, leaf litter mostly burned down to ashes. This variable is used as an indicator of fire severity upon the floor.

- **Soil surface where there is unburned leaf litter debris.** Estimate the percentage of surface that remains covered by intact, scorched or burned down leaf litter.
- **Leaf litter fallen after the fire or expected to fall soon.** Scorched crowns keep dry leaves on their branches for a short while. These leaves end up falling within some weeks and can act as mulch. Indicate whether this phenomenon is going to occur in the plot and the percentage of soil cover that it could bring about (Figure III-18).

Figures III-18. Soil covered by pine needles fallen after the fire.

- **Depth of leaf litter layer that remains after the fire** (in cm).
- **White ash:** high severity of fire upon the soil causes the resulting ash to be white or light grey. Determine whether in the plot: (a) there is white ash, (b) there is white ash only at some points where fuel accumulated (for example, large stumps consumed by fire), or (c) white ash is widespread (Figure III-19).

Figures III-19. On the top, presence of exceptional white ash under fuel accumulation. On the bottom, widespread presence of white ash, which suggests that the fire had a high severe impact on the soil.

- **Ash movements after rainfalls.** If it has rained between the fire and the inspection (as reported in sheet no. 2), indicate whether the rain has moved the ash only at specific spots or on a general basis.
- **Landslides/earth flows.** If there have been landslides after the fire, indicate whether exceptional or widespread within the plot.
- **Breakdown of walls on terraces.** If there have been wall or embankment breakdowns after the fire, indicate whether exceptional or widespread within the plot.

G. REMARKS

Other relevant features to assess erosion risk or vegetation recovery: recurrence of fire, when data available, presence of motorcycle trails or livestock trails, signs of high density of herbivores, etc.

SHEET 3. SAMPLING/OBSERVATION POINT		Date of sampling: ____/ ____/ ______	
POINT NUMBER:		Points assigned by similarity	

A) GENERAL DATA

UTM x: UTM y: Altitude (m):

Dominant relief: flat, summit, butte, piedmont, glacis, valley/ravine bottom, convex/concave hillside.

Dominant orientation: **N** NE **E** SE **S** **SW** **W** NW TV

Dominant gradient:

(percentage)	<15%	15-30%	30-45%	>45%
(degrees)	<7º	7-15º	15-25º	>25º

Silvicultural activities conducted within affected area:

On vegetation (repopulation, silvicultural treatments, etc.):______________________

On the soil (subsoiling, hole digging, terracing, etc.):_____________________________

Evident causes of soil degradation (overgrazing, landslides, runs, etc.)

Indicate the main ones:

B) PLANT HEALTH STATUS

Presence of pests, disease or damage due to abiotic factors: NO YES

Affected species	Causative agent	Impact level	Risk of spreading

Impact level: 1= light 2=moderate 3=severe.

Risk of pest or disease spreading: 0=insignificant 1=light 2=moderate 3=severe

C) PRE-FIRE SOIL STATUS

Lithology		**Land**	

Soil depth (dominant): surface (<30 cm) deep (>30 cm)

Effervescence to HCl: no little active

pH value of mineral soil between 0 and 5 cm:

Erosion type (indicate intensity for each type: None / Light / Moderate / Severe)

Laminar erosion_______________ Badlands_____________________________ Landslides ____________________________

Rills_______________________ Accumulation_________________________ Breakdown of walls ____________________

Gullies_____________________ Erosion/Wind erosion__________________ Others_______________________________

Existence of terraces

None	A few	Many

Vegetation on terraces: Active crops Abandoned but not colonised Colonised by forest vegetation

State of terraces: Good condition Exceptional breakdowns Widespread breakdowns

D) PRE-FIRE VEGETATION

Trees

CCF %	

Distribution: uniform, isolated trees, trees and shrubs/grassland mosaic, adult tree and regenerated mosaic

Species	Space occupied	% Reforested	% Sapling phase	% Poles phase	% Old-growth

Origin of dominant forest Planted Natural or without evidence of plantation

Serotinous species:

Forests with few cones Forests with abundant cones Forests without cones (generally regeneration pine woods)

Scrubs

% Total scrub cover <30% 30-60% >60%

Species	Space (0-10)	Species	Space (0-10)

% Floor covering with resprouting species: <30% 30-60% >60%

Herbaceous stratum

% Total herbaceous cover: <30% 30-60% >60%

Species	Space (0-10)	Species	Space (0-10)

% Herbaceous cover with resprouting species: <30% 30-60% >60%

Fuel model (1 to 13)	

SHEET 4. SAMPLING/OBSERVATION POINT		Date of sampling: ____/ ____/ ______	
POINT NUMBER		Points assigned by similarity	

E) POST-FIRE VEGETATION STATUS

Severity of impact on trees

Species	Low	Medium	High	Very high	% of trees under each severity class

Low: partially affected on trunk base, green crown
Medium: partially affected trunk, >50% green crown
High: >50% dry leaves on crown; they can be on the floor if inspection is carried out several weeks after the fire
Very high: fully burned, burned down leaves

Are there any pine nuts on the ground? no yes a few Many

Severity of impact on scrubs

Low	*Over 50% of scrubs remain unaffected or present large green areas*
Medium	*Over 50% has been affected, even though there are some plants with green areas*
High	*The whole scrubland has burned (no green leaves) but some twig ends remain unburned*
Very high	*Completely scorched (only the thickest branches, approximately >6mm, remain standing)*

Severity of impact on herbaceous stratum

Consumed Partially burned Many green areas left

F) POST-FIRE SOIL STATUS

% Bare soil (no vegetation, leaf litter or stones): <30% 30-60% >60%
Rock fragments (% cover): Bare to slightly stony (<20)
Stony (20-60) Very stony (>60)
Rocky outcrops: no exceptional frequent widespread
Rate of soil crusting: None Minor Moderate Severe
Significant presence of patched or continuous biological crust? Yes No

Soil horizons

Affected leaf litter: intact partially burned Consumed

% soil surface where unburned leaf litter debris: <30% 30-60% >60%
Leaf litter fallen after the fire or expected to fall soon (pine needles): yes no
% of soil covered by leaf litter in the short-term: <30% 30-60% >60%
Depth of leaf litter layer remaining after the fire
surface (<1 cm) thick (1-3 cm) very thick (>3 cm)

White ash: Mostly absent Exceptional: only under accumulated fuel

	None	Exceptional	Widespread
Ash movements after rainfall			
Landslides/earth flows			
Breakdown of walls on terraces			

G) REMARKS

■ Fire Impact Assessment

Having gathered the information, the ecological impact of the fire is assessed. At this point, the data gathered in plots, along with the rest of cartographic and alphanumeric information, are summarised and processed so as to facilitate the assessment process. The assessment comprises information on short-term ecological vulnerability and fire severity (Figure III-20).

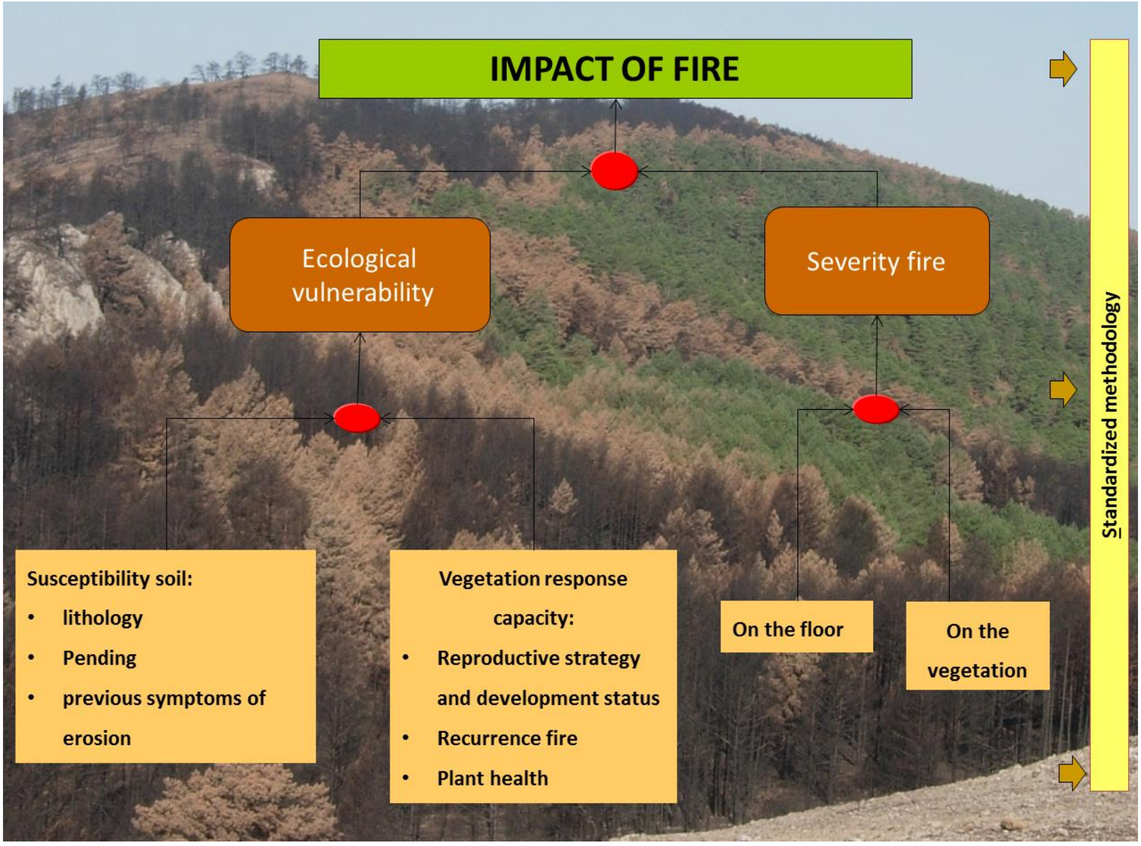

Figure III-20. Ecological impact of a fire depends on short-term ecological vulnerability in the forest stand and on fire severity.

Short-term ecological vulnerability

The vulnerability in the burned area is estimated based on the sensitivity of the floor and on the strength of vegetation response (Figure III-20). The selected indicators are as follows:

- Soil sensitivity is assessed through lithology data (as an erodibility indicator, in the absence of information detailing soil features), gradient, erosion signs prior to the fire and soil protective covers (stoniness, leaf litter) (Chart III-8).
- The sensitivity of vegetation is assessed through the vegetation response capacity which, at the same time, depends on the features of each vegetation stratum (composition, reproductive strategy, maturity, covering), its plant health status and the recurrence of fires (Chart III-8).

On Chart III-8, the selected indicators are set out, along with the established categories and ranges. These ranges are only for orientation purposes and can be put into context or changed depending on the different territories where the assessment is conducted and as per the criteria of the expert conducting the assessment.

By applying the intervals defined under Chart III-8 to the quantitative information obtained in sampling points, we can obtain an objective and standardised assessment of vulnerability. The assessment can be conducted for each point for a specific environmental unit and for the whole of the fire.

Chart III-8. Variables used to estimate ecological vulnerability in the short term for large fires in the Autonomous Community of Valencia.

<table>
<tr><th colspan="3">VULNERABILITY</th><th>LOW</th><th>MEDIUM</th><th>HIGH</th><th>VERY HIGH</th></tr>
<tr><td rowspan="7">**Land**</td><td colspan="2">Topography (Pending)</td><td><15%</td><td>15-30%</td><td>31-45%</td><td>>45%</td></tr>
<tr><td colspan="2">Lithology[a]</td><td>TYPE I</td><td>TYPE II</td><td>TYPE III</td><td>TYPE IV</td></tr>
<tr><td rowspan="3">Previous signs of erosion</td><td>Degree of erosion</td><td>None / Minor</td><td>Moderate</td><td>High</td><td>Severe</td></tr>
<tr><td>Terrace status</td><td>None or in good condition</td><td>Exceptional breakdowns</td><td>Widespread breakdowns</td><td></td></tr>
<tr><td>Degree of crusting</td><td>Minor</td><td>Moderate</td><td>Severe</td><td></td></tr>
<tr><td rowspan="2">Soil protection</td><td>% Bare soil</td><td><30%</td><td colspan="2">30-60%</td><td>>60%</td></tr>
<tr><td>Leaf litter layer thickness</td><td>>3 cm</td><td>1-3 cm</td><td><1 cm</td><td></td></tr>
<tr><td rowspan="5">**Vegetation**</td><td rowspan="3">Response capacity</td><td>CCF of *P. halepensis*/ *P. pinaster* in pole/old-growth stages or resprouting trees</td><td>>60</td><td colspan="2">30-60</td><td><30</td></tr>
<tr><td>Resprouting scrub covering</td><td>>60</td><td colspan="2">30-60</td><td><30</td></tr>
<tr><td>Resprouting herbaceous covering</td><td>>60</td><td colspan="2">30-60</td><td><30</td></tr>
<tr><td>Fire recurrence</td><td>Number of previous fires in the past 20 years</td><td>0</td><td>1</td><td>2</td><td>>2</td></tr>
<tr><td>Plant health status</td><td>Presence of pests and/or presence of damage by abiotic agents</td><td>Minor or non-existent</td><td>Moderate</td><td>High</td><td></td></tr>
</table>

[a] The most common lithology types are grouped in these categories: TYPE 1: limes; dolomites; limes with dolomites or calcarenites; limes and sandstone. TYPE 2: marly limestones; calcarenites; tophaceous limestones; conglomerates; conglomerates and clays; limestones and marls; flysch; calcarenites and marls; dolomites and marls; slates, schists and quartzites. TYPE 3: granites, conglomerates with clays; TYPE 4: sands; clays; clays with sands; gypsum; marls; clays with marls or silts.

Fire severity

Severity is a way to measure the level of consumption of living or dead organic matter caused by fire and is estimated from the data collected on the field, the vegetation and the soil surface. This estimation can be complemented using the severity values obtained from satellite high-resolution images when possible to obtain them quickly (Figures III-12 and 22).

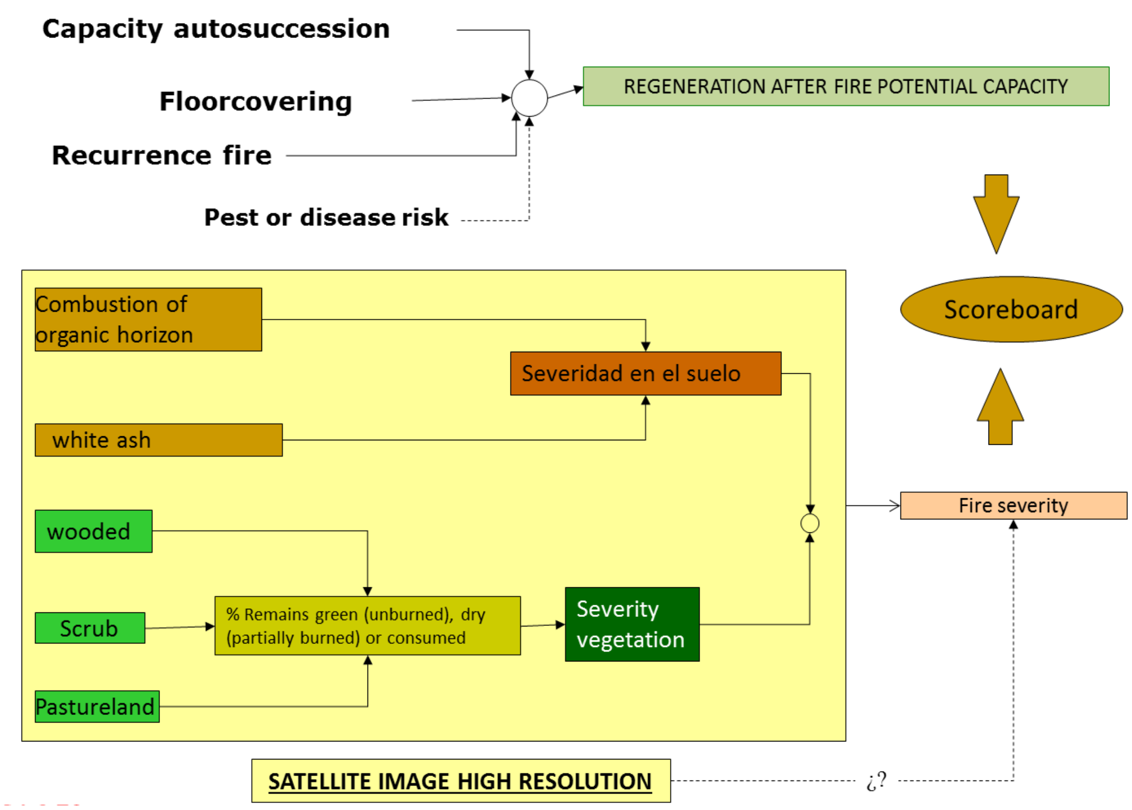

Figure III-21. Diagram used to assess fire severity, including field measures. The assessment can be complemented with indices obtained from remote sensing images (see Figure III-22).

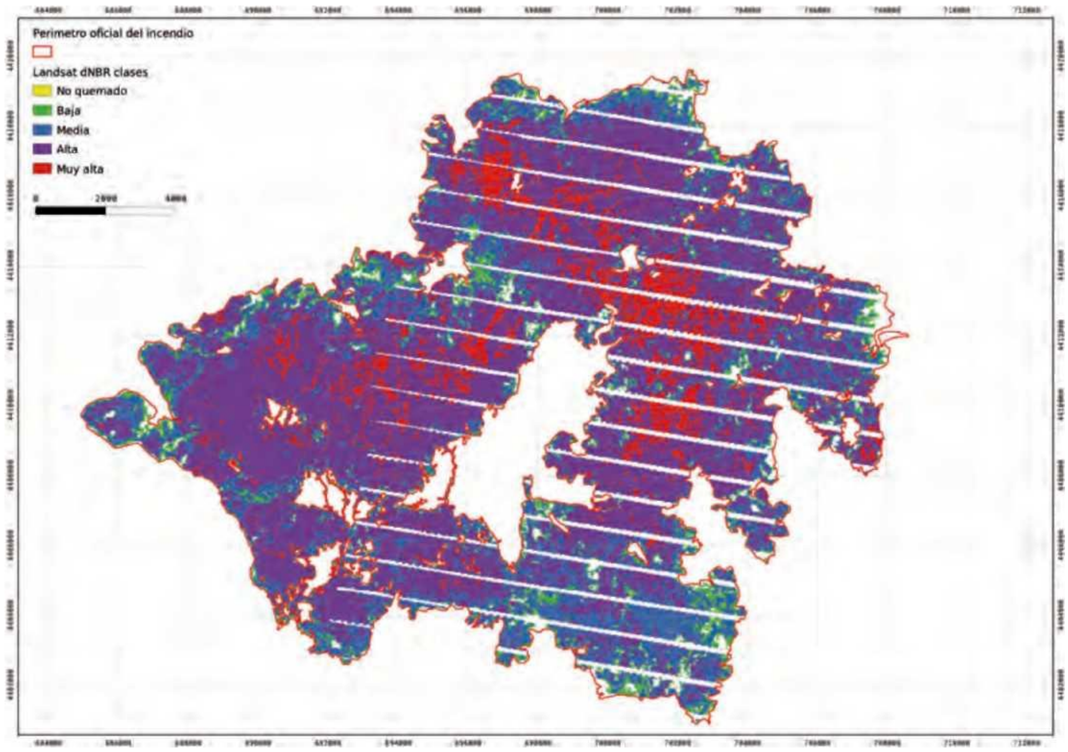

Figure III-22. Estimation of severity of Andilla fire (June 2012) through Landsat images. The severity values correspond with the dNBR list (Key & Benson, 2006): yellow: not burned (0-0, 140), green: low severity (0.1 - 0.70), blue: moderate (0.71-0.165), brown: high (0.166-0.300), red: very high (0.301-0.5); white stripes correspond to the areas without information due to a fault in the Landsat 7 sensor. The image was processed in July 2012, taking as reference the situation prior to the fire, the image dated 05/05/2012 and the image dated 19/07/2010 as a reference of the after-fire situation.

The severity upon the soil is assessed through the level of impact on the soil horizon and the presence of white ash. The severity upon vegetation is assessed through the level of impact on each of the strata. The indicators proposed for this assessment are set out in Chart III-9. Keys can also be found in Vega et al (2013a), Pereira & Bodí (2013) and Lozano y Jiménez-Pinilla (2013).

Chart III-9. Variables used to estimate fire severity

SEVERITY		LOW	MEDIUM	HIGH	VERY HIGH
Severity upon soil	Leaf litter affected (level)	Intact	Partially burned	Burned down	
	Presence of white ash	None		Exceptional	Widespread
Severity upon vegetation	Trees	Partially affected trunk	>50% green crown	>50% dry leaves on crown	Burned down leaves
	Scrubs	Forest stands are hardly affected	Plants with some green leaves	Some unburned twigs	Only thick branches left
	Herbaceous stratum	Green patches	Partially burned	Consumed	
Other specific impact signs					

Charts III-8 and III-9 separately combine the variables and scales recommended to assess vulnerability and severity. This information can be analysed for each sampling point in a summary sheet (Chart III-10), which can be used to analyse the distribution of vulnerability and severity categories. At the same time, the information in this sheet can be summed up in a chart showing the percentage of points for each of the vulnerability and severity categories (Chart III-11).

Impact assessment is conducted for each of the identified units, as per the distribution of vulnerability and severity categories (Charts III-8/III-11). The assessment can be completed at this point or, according to each specific situation and to the experience of each expert conducting the assessment, data can be aggregated so as to provide a final impact value, both for each unit and for the whole fire. Given the flexible and guidance-oriented nature of this guide, the criteria for data integration and the applicable weighting values are to be decided by the expert conducting the assessment.

Chart III-10. Sheet summarising the vulnerability and severity at each sampling point. For each point, the box applicable to the existing value of each assessment variable must be checked. For the sake of an easier interpretation, green colour is assigned to low vulnerability or low severity values and orange to high vulnerability or high severity values.

Environmental unit	Point No	VULNERABILITY																																			
		Land																					Vegetation														
								Previous signs of erosion									Soil protection						Response capacity														
		Gradient			Lithology			Degree of erosion			Terrace status			Degree of crusting			% bare soil			Leaf litter layer thickness			Mature serotinous or resprouting forest			Resprouting scrubland			Resprouting herbaceous species			Recurrence of fires in the past 20 years			Damages resulting from pests and/or abiotic agents		
		<15%	15-30%	>30%	Type I	Type II	Types III, iv	None/Minor	Moderate	High/Severe	Good condition	Exceptional breakdown	Widespread breakdown	None/Minor	Moderate	Severe	<30%	30-60%	>60%	>3 cm	1-3 cm	< 1 cm	CCF > 60%	CCF 30-60%	CCF < 30%	Cover > 60%	Cover 30-60%	Cover < 30%	Cover > 60%	Cover 30-60%	Cover < 30%	0	1	>1	Minor / None	Moderate	High
A	1																																				
	2																																				
	3																																				
	...																																				
B																																					

Environmental unit	Point No	SEVERITY															Other specific signs of impact
		Land						Vegetation									
		Leaf litter affected (level)			Presence of white ash			Trees			Scrubs			Herbaceous species			
		Intact	Partially burned	Burned down	None	Exceptional	Widespread	>50% green crown	>50% dry leaves	Burned crown	Green leaves	Thin twigs	Thick branches	Green patches	Partially burned	Burned down	
A	1																
	2																
	3																
	...																
B																	

Chart III-11. Summarising chart to estimate ecological impact based on the distribution of the percentage of sampling points existing in each vulnerability and severity categories.

Percentage of points		LOW	MEDIUM	HIGH	VERY HIGH
Unit 1	VULNERABILITY				
	Land				
	Vegetation				
	SEVERITY				
	Land				
	Vegetation				
Unit n	VULNERABILITY				
	Land				
	Vegetation				
	SEVERITY				
	Land				
	Vegetation				
Fire	VULNERABILITY				
	Land				
	Vegetation				
	SEVERITY				
	Land				
	Vegetation				

■ Recommendations

The information gathered during the field inspection enables the identification of the most vulnerable areas and the severity level of the fire. To complete the assessment process, a final analysis and recommendation phase is required. As a result, when necessary it will be required to specify the most urgent actions needed to stabilise the burned area and prevent risks (Napper, 2006; Vallejo et al., 2009; Vega 2010; Moreira et al., 2012; Vega et al., 2013; de las Heras, 2013), giving priority to areas with high erosion risks and to those where the response of vegetation is not sufficient (Figure III-23).

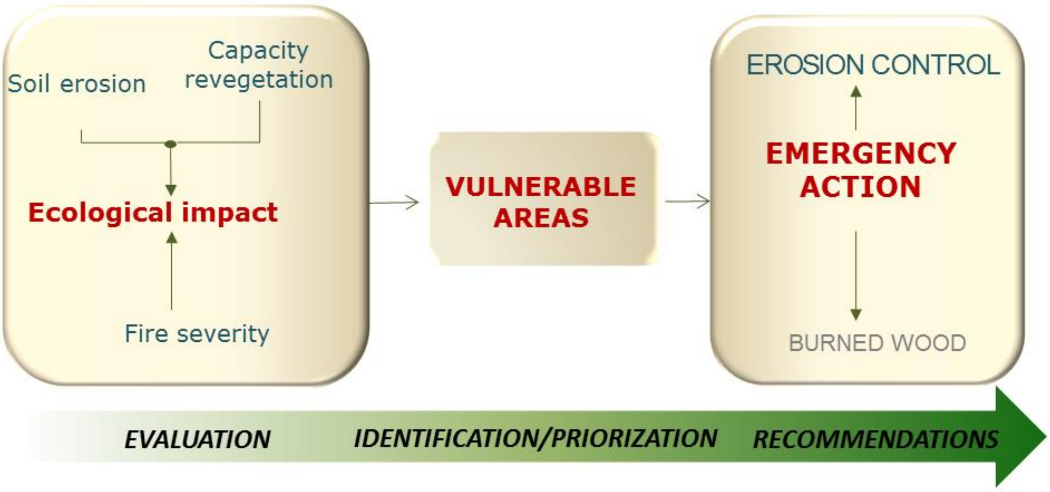

Figure III-23. Summary of the process followed for the recommendation of urgent actions.

In this field, the main risks we have to foresee are those arising out of runoffs in hillsides and the management of burned timber. In both cases, efficient solutions require the utmost urgency in the identification of alternatives.

Risk of hillside erosion

Soil degradation and erosion risks as a result of the loss of vegetation cover usually are the most critical processes after a fire (Vallejo, 1999). To prevent these risks, the areas requiring action are mostly located in hillsides where some of the following factors are present: risk of intense rainfall, steep slopes, erodible soils and dominance of germinating species (Figure III-24).

If the risk of intense rainfall is major and the fire has severely affected a very large catchment basin, a hydrological analysis must be performed so as to plan the specific treatments for water streams so as to prevent damages caused by floods. With regard to river basins, several methods can be applied after a fire to analyse the production of sediments and run-off. Bautista & Mayor (2010) describe methods to assess and monitor the impact of fire at a river basin level. Estimations based on models can be obtained applying the curve number model (NRCS, 1986), the aforementioned RUSLE model or the WEPP model (Elliot et al., 1999). Robichaud & Ashmun (2012) describe models and applications developed in the U.S. In our conditions, a detailed hydrological study on the impact of a fire is available in Delgado et al (2005). Also, in Cancelo-González et al (2013) there is a comparison between a burned basin and an unburned one in Galicia.

Detailed hydrological analyses and, above all, actions upon rivers require analyses and execution during several months. In any case, it is instrumental to assess the need to perform emergency actions in the most vulnerable hillsides (to be performed prior to the first autumn rains). In these cases, the basic criteria to select the techniques that could be applied may be used as a support system for decision-making processes (Figure III-24):

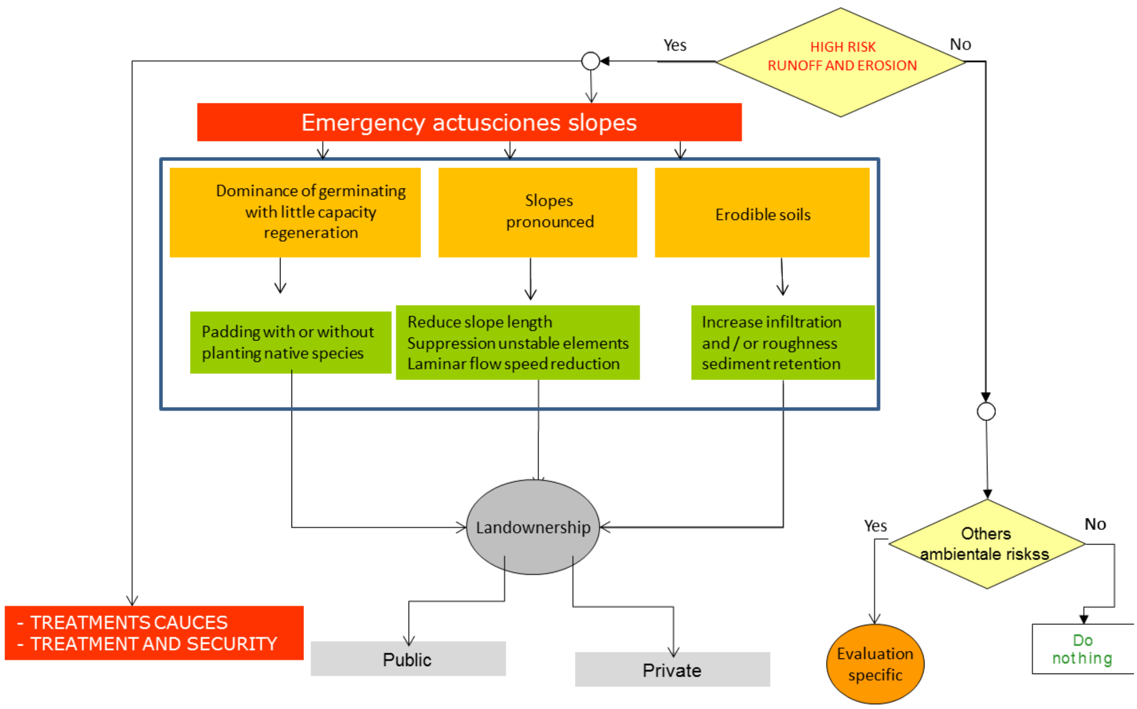

Figure III-24. Diagram of support to decision-making process to assess the need to apply emergency actions to fight erosion in hillsides.

ACTUACIONES DE EMERGENCIA EN LADERAS	EMERGENCY ACTIONS IN HILLSIDES
Dominancia de germinadora con escasa capacidad de regeneración	Dominance of germinating species with low regeneration capacity
Alcochado con o sin siembra de especies autóctonas	Mulching with or without seeding of indigenous species
Pendientes pronunciadas	Steep slopes
Reducir longitud de ladera Supresión elementos inestables Reducción velocidad flujo laminar	Reduce hillside length Suppression of unstable elements Reduction of laminar flow speed
Suelos erosionables	Erodible soils
Incrementar infiltración y/o rugosidad Retener sedimentos	Increase infiltration and/or roughness Retain sediment
Propiedad del suelo	Soil ownership
Público	Public
Privado	Private
TRATAMIENTOS EN CAUCES TRATAMIENTOS DE PROTECCIÓN Y SEGURIDAD	RIVER BED TREATMENT PROTECTION AND SAFETY TREATMENTS
ALTO RIESGO DE EROSIÓN Y ESCORRIENTIA	HIGH RISK OF EROSION AND RUN-OFF
Sí No	Yes No
Otros riesgos ambientales	Other environmental risks
Evaluación especifica	Specific assessment
No hacer nada	No action

In Addendum III "Emergency actions to control hillside erosion", there is a compilation of techniques aimed to control hillside erosion. The information includes a description of the techniques and the results obtained upon their application.

Burned timber management

In burned tree areas, one of the first questions to ask is how convenient it is to remove burned timber. Logging (or lack thereof) is a complex decision that highly depends on the conditions of the site (Peterson et al., 2009; Vega et al., 2013a). In addition, there is not sufficient evidence-based information (Perterson et al., 2009; Rodríguez et al., 2013) and this is a topic that frequently stirs up controversy (and not only in this field; Lindenmayer & Noss, 2006, Donato et al., 2006; Peterson et al., 2009).

When making this decision, consideration must be taken of not only ecological factors, but also socio-economical factors at a local level that could affect the management of burned areas. Sometimes the decision-making process with regard to the need to perform this action, as well as the time and the procedure to be applied, is influenced by the search for economic profitability that will enable the performance of this action, either in full or in part, and which can bring about some economic benefits for the owner (Peterson et al., 2009; Vallejo et al., 2012). This is a determining factor when burned areas used to be of a productive nature. The profitability of this actions is also limited by the available technology, the time elapsed between the fire and the harvest, the distance to communication routes and the volume of available timber. All of these factors influence the total harvesting cost. This is why the price of burned timber does not always allow financi the operation and can even originate additional costs during the restoration process of the burned areas (Leverkus et al., 2012). As a result, the manager often has to face the challenge of finding the balance between the exploitation of resources and the sustainability of management (Vega et al., 2013a). This challenge presents many obstacles, particularly for large-sized fires where hundreds of thousands of cubic metres of timber are generated along a process that takes two or more years and that is conditioned by environmental, technical and administrative factors and which has to fulfil several goals at the same time (for example, the fire in El Rodenal in 2005 in Guadalajara, Chavarría et al., 2010).

In general terms, some of the possible goals to justify timber harvesting in the short term are:

a) Ecological

- Protection against erosion.
- Reducing the risk of pests or post-fire mortality.
- Avoiding damages to tree regeneration in the future.
- Reducing fire risks in the future.
- Improving the stability and the growth of forests of *Quercus*, encouraging the resprouting of stumps.

b) Non-ecological

- Economic.
- Facilitating the recreational use and the security of residential or traffic areas.
- Avoiding risks upon the infrastructure and the road network.
- Reducing landscape and emotional impact.
- Facilitating the walkability of forest areas and post-fire forest management.

Figure III-25. Fire of adult trees on a hillside with steep slopes. Risk of falling or being dragged upon infrastructures (reservoirs, roads, power lines,...)

However, consideration must also be taken of potential negative effects: loss of nutrients; upturn in run-off and erosion of sensitive soils; damage upon regenerated areas depending on the time elapsed since the fire; increase in radiation and, as a consequence, in hydric stress; impact on bird fauna and dispersal of species. In Peterson et al. (2009), Castro et al. (2013) and Vega et al. (2013a), there is a wide range of bibliographic references about the management of burned timber in the climate conditions of the U.S. West Coast, the Mediterranean and the Atlantic.

On a general basis, the management of burned tree areas has several goals. In addition to ecological criteria, other needs are taken into consideration (of a social or economic nature, among others. In any case, it is recommendable to clearly define all goals, to split the area of operation in stands and to design treatments and a calendar that fulfils the established goals and respects the features of the natural environment. During the decision-making process in this regard, a three-step analysis procedure can be established (Figure III-26):

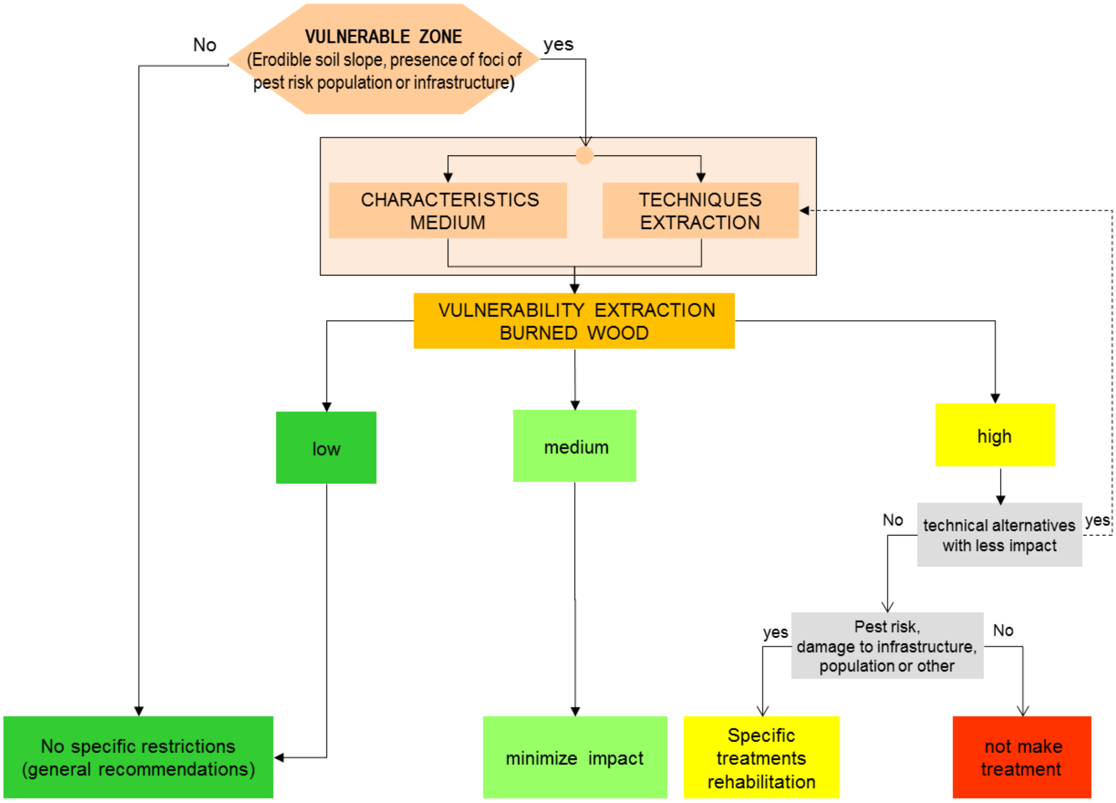

Figure III-26. Diagram for decision-making regarding burned timber extraction.

- Identification of potentially vulnerable areas. Potentially vulnerable areas generally are those where there are burned trees and which stand on soils that are prone to erodability and in moderate or steep slopes. Also the stands near pest sources are especially vulnerable, as are those that can present risks for the population or infrastructure.
- Assessment of vulnerability to the harvest of burned timber through the integration of information about the natural environment and the potential impact of burned timber harvesting.
- Decision-making depending on the vulnerability analysis. If negative impact cannot be avoided, consideration must be taken of the available options to minimise it. When facing extreme negative impact, the application of post-action rehabilitation techniques must be considered. Another possibility is to not perform such actions if there is no risk of pests upon infrastructure or people, or postpone the actions until the forest is not as vulnerable. In areas without specific restrictions, a rapid harvest of burned timber can be carried out, provided that general recommendations are followed.

This guide provides some advice so as to help the decision-making process regarding burned timber harvesting. A qualitative assessment is proposed, applying information, criteria and methods similar to those applied in fire impact assessments. During this process, the most relevant ecological factors that can be affected by burned timber extraction are identified, and then assessed (according to a qualitative method) through some indicators. For this purpose, a double-entry table must be used (Chart III-12). The ecological factors proposed for assessment are:

- Soil conservation. The potential impact of timber harvesting highly depends on the logging procedure, the erodability of the soil, the soil surface affected within the stand and the intensity of timber skidding (Mayor et al., 2002; Bautista et al., 2004; Peterson et al., 2009).
- Vegetation cover regeneration. The removal of wood can sometimes cause environmental changes. For example, the amount of radiation absorbed by the floor (Peterson et al., 2009; Castro et al., 2011). These changes can even change the germination and settlement features of seedlings, reducing the total covered area and causing a decrease in the number of species (generally of a temporary nature). If the harvest is not early, that is, before pine seedlings have settled, harvesting can cause their death, even though this would not have an impact on final density if regeneration is good (Bautista et al., 2004; Madrigal et al., 2007 and 2009; Vega et al., 2009a). However, damages upon regenerated areas have also been reported (Castro et al., 2012 and Castro et al., 2013). In holm oak forests, coppice is recommended to ensure strong resprouting (Serrada et al., 2008; Serrada & Bravo, 2012).
- Functional and structural role of dead timber. Trunks and branches on the floor reduce hydric stress of plants and constitute a reserve of nutrients absorbed by the floor (Marañon, 2011; Castro et al., 2013), and also affects CO_2 flows (Serrano et al., 2011; Powers et al., 2013). In addition, the presence of burned debris determines the physical conditions –spaces, enclaves, perches, microclimatic conditions- which can play a significant role in vegetation and animal post-fire succession (Herrando et al., 2009; Cobb et al., 2010; Rost et al., 2010, 2012).
- Risks of pest propagation as a result of the emission of volatile compounds by trees that have been partly affected by the fire and which attract woodboring insects (especially of the Scolytidae family; Bautista et al., 2004; Martín Bernal & Ibarra, 2010; Santolamazza et al., 2011).
- Impact of fuel accumulation (particularly fine fuel) upon the spreading and intensity of subsequent fires (Peterson et al., 2009).

To assess these factors, some indicators are proposed. We have tried to reduce the number of indicators to a minimum by choosing those that could provide the most relevant information about the areas to be assessed and the fire severity:

- Type of soil depending on the level of sensitivity to erosion phenomena. The same criteria as were applied in Chart III-8 are to be used here.
- Previous signs of erosion. Existence of relevant erosion systems within the area before the fire, which are prone to be enhanced by burned timber harvesting activities.
- Soil surface that is not protected against erosion phenomena. Percentage of soil not covered by remains of burned vegetation or leaf litter or pine needles fallen after the fire or by stone content.
- Physiography. The topographic effect is assessed as per the gradient, each interval being assigned an erosion sensitivity level: <15% (light sensitivity), 15-30% (average sensitivity) and >30% (high sensitivity). In terraced hillsides, if the conservation status of the wall is poor, the natural gradient of the hillside will be taken into consideration.
- Vegetation. The vegetation response capacity (in terms of the re-establishment of soil cover) is assessed through the abundance of species with resprouting strategies in herbaceous and scrubland strata before the fire. The level of development and canopy of the trees is also taken into consideration as a fuel input source.

- Presence of pest sources. In pine woods, risk of bark beetle pests extending, bearing in mind the existence of uncontrolled pest sources near the affected surface (at a distance under 2-4 km).
- Severity of the fire upon the soil. The level of impact upon soil horizons can affect the impact of timber skidding , the establishment of vegetation, the diversity and composition of species and the availability of mineral nutrients and food sources for micro-organisms.
- Severity of the fire upon tree crowns. The level of impact upon trees is determined through the percentage of the canopy that is green (intact), dry (partially affected) or burned down. The impact can have an inverse effect upon the risk of spread of pests (the lower the severity, the greater the number of trees partially affected by the fires and therefore the more likely to have pests). On the other hand, minor severity levels could encourage soil coverage as a result of the falling of pine needles from affected pines.

Figure III-27. Remains of burned wood arranged in stripes on a hillside.

The assessment method combines variable pairs with qualitative assigned values between ecological process and the indicator resulting from the environmental or fire features (only the most relevant combinations are considered). During the assessment, a colour scale is applied for the different sensitivity levels: orange for negative levels, dark colour for the most intense values and light ones for less intense or neutral values. Chart III-12 sets out a template with the proposed ecological factors, their indicators and an assessment (established according to general criteria) that can be altered or modified according to local details.

Chart III-12 sets out a guidance assessment of all factors taken into consideration. During the assessment process, the technical expert must choose all those representative features of the area to be assessed and, considering the potential effect upon the most relevant ecological factors in the area to be assessed, associate a colour scale to them. Through the "expert opinion" criterion, the assessment of each factor can be aggregated so as to estimate the vulnerability of the area. This assessment must be applied to areas with a specific extension but of a homogeneous nature when it comes to the environmental features analysed: physiography, soil features, type of plant formations and fire-related issues and the existence of bark beetle sources. In this regard, the units and sub-units differentiated in the inspection and in the information obtained at the sampling points can be applied. Addendum I shows an example of the method applied to an actual fire.

Chart III-12 also provides assessments of the potential impact upon each ecological factor by the types of treatment of burned timber (tree felling, full extraction, logging, stacking, chipping). As in the assessment of the natural environment, these assessments, whether positive or negative, are of a general nature and subject to changes depending on the criteria of the technical expert and on the specific features of the treatment and the area to be assessed.

Based on the specific features of the forest stand the technical expert will choose the most convenient treatment and, as indicated above, will adapt the assessment scale to the specific execution features, their time of execution and the extent of the treatment. For example, it is worth mentioning that chipping, by creating a layer over the soil, will have a positive impact upon soil conservation, help vegetation establish by reducing water stress, lower fuel loads and help nutrient recycling, although it will affect bird fauna. On the contrary, full extraction will have an impact upon the soil and vegetation, the importance of which will vary depending on the time of year when it is conducted. It will be a positive action for pest control and fuel and a negative one for nutrient recycling and bird fauna. As explained above, these general considerations could be subject to changes depending on the particularities of each assessment.

The global assessment will result from the distribution of impacts between the different ecological processes and selected indicators. In addition, it is possible to conduct a global integration of all assigned values to obtain one single value to illustrate the vulnerability of timber treatment. This integration will also require specific weighed factors as per the singularities of each case or according to the technical criteria of the person conducting the assessment ("expert opinion"), who may justify these decisions in an explanatory document.

Chart III-12. Ecological factors and indicators selected for the assessment of vulnerability to burned timber logging depending on the features of the site, the fire severity and the type of logging. In the colour scale, colour reflects the intensity of negative impact resulting from the treatment upon the indicators. Green colour reflects positive impact. Yellow colour will be different in each situation and grey indicates that data are not applicable. In each case, the most representative situation in the assessment area must be selected.

			ECOLOGICAL FACTORS									
				Regeneration of vegetation cover				Source micro-org., nutrients and food		Habitat for small animals	
			Soil conservation[1]	Establishment of vegetation, germination and settlement	Diversity and composition of species	Pest spreading	Total fuel	Food source fungi, insects and micro-org.	Source of mineral nutrients	Diversity of small forest vertebrates	Forest birds
SITE FEATURES	Substratum type	Hard materials									
		Crumbly									
		Poorly consolidated									
		Minor									

	Previous signs of erosion	Moderate									
		Severe									
	Bare soil area	>60%									
		30-60%									
		<30%									
	Gradient	<15%									
		15-35%									
		>35%									
	Resprouting species	>60%									
		30-60%									
		<30%									
	Tree development status burned	Fully thick old-growth development									
		Old-growth development (non thick) Pole phase or sapling phase, fully thick									
		Other									
	Others										
Presence of pest source within 2-4 km	FIRE	Low									
		Medium									
		High									
	Severity upon soil	Low									
		Medium									
		High									
TREATMENT	Treatment for debris	**No action**									
		Only tree felling									
		Trunk logging	*								
		Stacking									
		Chipping									
		Full skidding extraction	*								
FOREST STAND UNDER ASSESSMENT											
SELECTED TREATMENT											
STAND VULNERABILITY											

[1]The assessment of impact upon soil conservation can be carried out according to the selected logging method and its relevant time frames.

The recommendations proposed will be subject to changes according to, among other local-specific considerations, the extension of the stand under assessment and the time frame of the treatment (immediately after the fire, in the short term or within a period over two years).

Depending on the results, new alternatives can be proposed to minimise the impact of actions or for the rehabilitation of the area in high-impact cases. In those situations where the assessment according to ecological criteria shows high vulnerability levels or there are no other considerations that may justify the management of burned timber (for example, risk of pests or impact upon people or infrastructures), we recommend to avoid the treatment at all. Should there be other considerations justifying the logging, it is recommended to use alternatives with techniques of a lesser impact. For large burned areas where logging will inevitably extend over time, one alternative will involve putting off the logging of the most vulnerable areas so as to alleviate their vulnerability levels by allowing vegetation cover to recover. In average vulnerability cases, it would be necessary to change treatments or plan them out so as to lower their impact. In low vulnerability areas and non-vulnerable areas, no specific restrictions are established.

Figure III-28. Exploitation of burned timber for biomass production.

In any case, all burned timber treatments will be subject to general recommendations and minimum criteria to be taken into consideration in all burned timber logging treatments (Chart III-13).

Chart III-13. General recommendations for burned timber logging.

General recommendations	
• Act in a selective manner, adopting a precautionary approach (Bautista et al., 2004) and considering several possibilities. To the extent possible, adapt the treatments in each forest stand to the level of fire severity and the serotinous levels in it. • Avoid acting in stands with highly erodible soils, in steep slopes or areas with previous signs of erosion, at least until the vegetation has developed a protective cover of the soil. • In treatments over wide areas, leave some dispersed isolated or harvested trees and untreated areas distributed under a mosaic pattern aiming to foster the functional and structural role of burned timber (preferably large-sized trees). • Apply evidence-based technical criteria for tree felling on the account of plant health. For example, Bordón et al. (2012) set out some charts of survival probability of trees partially affected by fires depending on the % of burned crown, the % of standard perimeter affected and the % of height affected by fire. Rodrigo et al. (2009) and Vega et al. (2009b; 2013b), also set forth some criteria for partially affected tree felling. • Conduct periodic monitoring to assess the risks of pests in those trees most weakened by the fire. • Logging activities should not affect the status of conservation of walls or terraces or trigger new erosion processes. • In large fires, short-term logging of all timber targeted by commercial interests is impossible. This is why it is necessary to previously establish the criteria, time frames and features of the extraction plan to minimise damage. The areas most vulnerable to erosion can be extracted later on, once the ecosystem has recovered its protective vegetation.	
General recommendations for the main ecological factors and execution phase.	
Soil conservation	
Skidding	Minimise soil compacting using the most adequate technical methods for each situation. Avoid establishing timber extraction points in the most fragile hillside areas in terms of erosion (collapsed terraces, ravines, steep slopes, etc.) Avoid, to the extent possible, establishing new extraction routes.
Distribution	In the most flat areas, or the most accessible areas from logging routes, grind non-wood debris and scatter them on the floor. Pile up the debris according to level curves, particularly in the most sensitive areas. Endeavour to place wood debris in contact with the soil surface. If new extraction routes are to be created or old ones are recovered, precautionary measures must be taken to avoid triggering new erosion processes or landslides.
Time frame	In highly erodible and steep strata, avoid immediate action after fire that would leave the soil bare. In the most vulnerable areas, for the purpose of minimising the negative impact upon the floor, wait for a protective vegetation cover to settle.
Vegetation cover	
Retention	Burned timber treatments can modify radiation rates. Full removal of burned timber increases direct radiation rates upon the floor. On the contrary, the distribution of debris can help increase shadow zones, which can help the

	settlement and growth of some species.
Distribution	Chipping or the dispersal of debris on the surface (not covering 100% of the area with >3-cm thickness layers) improves germination and seedling settlement.
Area	Perform treatment on stands individually, avoiding homogeneous treatments for large surfaces.
Time frame	If intense skidding extraction is conducted when plants have already settled, significant damage could be caused for species with low regeneration capacity. Should there be problems in pine wood regeneration or should total vegetation cover rates be low, do not perform late intense activity.
Pest spreading (bark beetles)	
Retention	Remove pine trees partially affected by fire (more sensitive to become infected). Monitor the condition of the most weak trees and of the insect population so as to prevent their potential infection.
Distribution	Do not leave partially burned wood debris on the hillside, neither scattered or stacked. Pine tree trunks affected by fire that are used for building fascines to protect the soil from erosion must be previously barked. Chipping wood debris could be a good solution that also contributes to improve soil conditions and lessen the impact of other factors.
Area	Stick to areas subject to be affected by nearby bark beetle sources detected or by the impact severity of pines.
Time frame	Extractions to be conducted in several phases along the life cycle of the bark beetle (always start within a year).
Load of stacked timber	
Retention	The retention of stacked burned timber could become a dangerous fuel load as a result of the most fine timber fractions that can accumulate.
Distribution	Avoid treatments concentrating materials that burn easily in large stripes or continuous lines. These lines or stripes could help fire spread in the future and could also hinder fire fighting activities. A large concentration of thick wood in stacks (fascines) could bring about new fires in areas with high potential severity.
Area	Conduct treatments upon specific areas or spots. Treatments must not be homogeneous to avoid large areas with continuous loads that can burn easily. Create a heterogeneous landscape that contributes both to the recovery of the plant community and to fire fighting tasks in the event of fires in the future.
Biodiversity / habitats /fauna / fungi	
Area	Action performed on each forest stand individually, instead of on all of them at the same time. Untreated forest stands are useful for forest bird fauna, insects, wood-decay fungi and tree-dwelling vertebrates. Leave isolated or harvested trees and untreated copses across the whole area.

■ Example of application, required logistics to draft assessment reports

As explained above, the method is flexible enough to adapt to the environmental and technical features of each area and to those arising out of the fire, particularly the ones regarding the surface. Another relevant feature of the method is its capacity to offer a diagnosis of the fire impact alongside emergency recommendations only a few weeks after the fire has been extinguished, all of which can be conducted at an affordable cost.

The complexity of the process to be assessed has a significant technical dimension, both with regard to the application of assessment criteria and to the required tools (GIS, database, etc.). That is why assessments are proposed to be conducted by teams made up by two versatile or complementary technical experts with knowledge of the field and of the necessary computer tools. These teams could be made up by a technical expert specialised on assessments and a forest ranger with specific training. In large fires, so as to have the assessment and recommendations drafted with utmost urgency, several teams have to be working simultaneously. In this case, criteria must be standardised before conducting any actions.

The method has been validated since 2010 through its application to more than 10 fires in the Autonomous Community of Valencia, the burned areas of which ranged between 100 ha to 30,000 ha.

The application of the methodology has turned out to be particularly relevant in two large fires of over 20,000 ha that occurred in Valencia during the summer of 2012. In late June, the forest fires of Andilla (20,935 ha) and Cortés de Pallas (29,752 ha) took place. Both fires, which developed almost simultaneously, have allowed us to compare the applicability of the method, both with regard to the affected area, the intensity of inspections (for example, over 150 sampling points were assessed; Figure III-29) and the immediate nature of the assessment (the report was drafted within the first ten days of August). Assessment conducted by 4 teams made up by 2 technical experts each working on the field and drafting reports, and another team made up by 2 technical experts for coordination and support tasks.

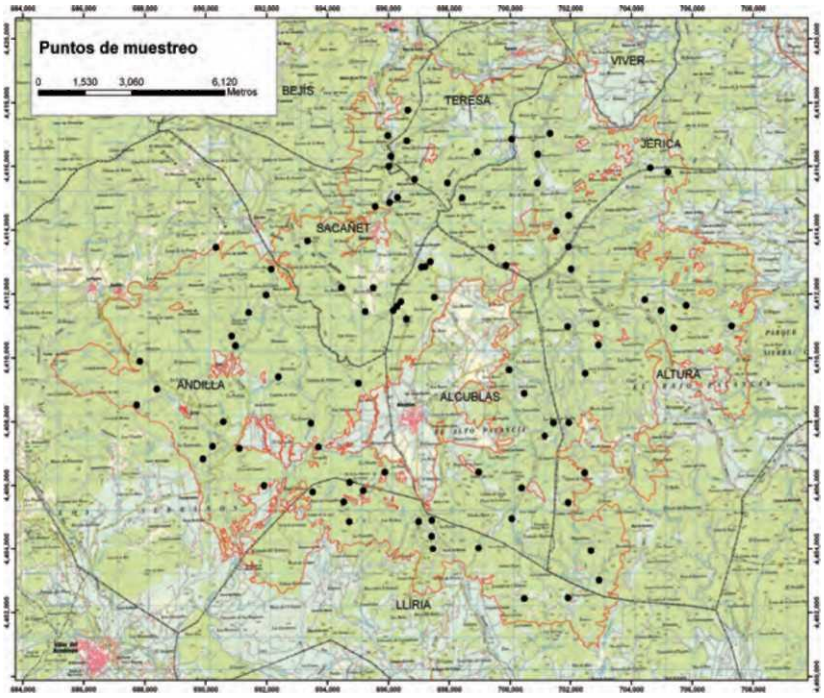

Figure III-29. Distribution of sampling points at the Andilla fire (2012)

In terms of cost and organisation, the application of the method in an average fire (1,000-3,000 ha) could be broken down into the following terms:

- Documentation Phase. Desk research for the search of cartographic information and features of the fire and the area involved:
  - ✓ Creation and printing of thematic mapping, sampling grid: 1 work day by a technical expert with GIS knowledge and for documentation.
  - ✓ Gathering and analysis of data, preparation of inspection routes: 1 work day by a technical expert with experience in assessment methodology.
  - ✓ Resources: computers, printers and GIS.

- Inspection Phase. Routes and data collection in affected areas.
  - ✓ Team made up by a technical expert with experience in methodology and a supporting technician: 3 days of field work.
  - ✓ Resources: 3 days of off-road vehicle, GPS, photographic camera, basic material for field determination.

- Assessment Phase. Drafting of report with impact assessment and emergency recommendations. 3 sessions with the technical expert are required.

- Other tasks: Organising gathered information, maintenance databases, photo files, etc., estimated in 1 work day of a technical expert.

In Addendum I: "Aplicación del protocolo de evaluación al incendio de Vall d'Albaida 2010" (Application of assessment protocol to the Vall d'Albaida 2010 fire) describes in depth all of the steps taken in the application of the ecological impact assessment method of a 3,000 ha fire that in September 2010 affected several Southern municipalities of Valencia and the North of Alicante. The addendum summarises the report drafted for the Regional Ministry of Infrastructures, Land and the Environment of the Regional Government of Valencia.

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TECHNICAL GUIDE TO THE MEDIUM-TERM ASSESSMENT OF FOREST FIRE ECOLOGICAL IMPACT

■ INTRODUCTION

As previously stated in the introduction, assessing the impact of a fire must be done with utmost urgency, in order to identify and, if possible, to implement the procedures to prevent the erosion risk, on time and on the field. The time frame between a forest fire (mainly in July and August) and the first autumn rains (often torrential) is small and logistics or necessary measures are not always available to address an urgent procedure plan requiring a large budget. Accessing private land is an extra difficulty.

On the other hand, excepting the most vulnerable areas, urgent and indiscriminate intervention could harm vegetation regeneration, especially if it got rid of the ground protection offered by pine needles (Madrigal 2010, 2011). It would also mean inefficient use of permanently limited economic resources. In any case, given that large-scale fires are relatively frequent and likely to continue happening, society and technical infrastructures should be prepared to respond efficiently in order to minimise damage. EU initiatives in the field of civil protection and in response to natural risks (and semi-natural risks like forest fires) are in line with this mindset.

Vegetation regeneration happens naturally over time, which includes important structural changes and also, to a lesser extent, changes to plant composition. In this way, after the first months of risk in which the soil is partially devoid of vegetation, after 1-3 years a stage is generally reached in which plants cover reaches 100% (obviously excepting rock outcrops). In this first recovery period a proliferation of opportunistic plant species can be produced (Trabaud & Lepart, 1980), making use of the free space and causing a temporary increase in species numbers. This process is conditioned by the type of affected vegetation and environmental conditions (meteorological conditions from after the fire and soil), which equally affects the severity, growth, period and recurrence of the fire (Casal, 2010).

In relation to the evolution of vegetation composition and structure, about 3 years after a fire comes a critical turning point in the changing plant cover (Casal, 2010). In this sufficient time frame germination of woody species will have already taken place and diminished the presence of opportunistic herbaceous species. Therefore, it is the adequate moment to evaluate the plant cover dynamics in terms of coverage, structure and composition, as well as to evaluate, if needed, the efficiency of emergency actions and to plan the need for new actions.

In any case the moment for the medium-term assessment to take place will have to be sufficient in the absence of other administrative and/or economic considerations of the area in question, mainly in regard to the evolution of vegetation.

The criteria stated in this guide could equally be applied if an assessment of the impact of the fire has previously been carried out, such as the first diagnosis of the affected area. Turning to the integral nature of the methodology, the information required in this phase can support previous phases, depending on the information available, to be carried out with more or less intensity.

■ FIELD INSPECTION

As in the previous stage, in this guide some guidelines are established for a diagnosis based on an inspection of the area. The technical and working characteristics of the inspection are basically the same as those indicated in the emergency assessment (previous section), but with some specific inventories.

The sampling points can be distributed in the territory following the same indications as in the emergency sampling. If emergency sampling was carried out in the past, the same sampling points will be maintained if possible. However, sometimes it is interesting to conduct monitoring reports about points with no previous data (for example areas in which specific post-fire treatments have been carried out).

■ FIELD INVENTORIES

Inventories maintain the same structure as those used in emergency inspections[12]. In this way, when sampling points for the first time, the file sections about sampling/observation must be filled out: (A) General data; (C) Pre-fire soil status (except pre-fire erosion data that can be difficult to distinguish); and the data corresponding to low stone content and isolated outcrops, (G) Post-fire soil status.

Specific information from the sampling assessment can be summarised in the following sections:

A) SOIL STATUS. This section covers the variables related to post-fire erosion and the current erodability of the soil.

- **Type of erosion/accumulation:** describe all the active processes in the sampling points (laminar erosion, in rills, gullies, badlands, accumulation, wind erosion, breakdown of walls, landslides, etc.) and the intensity of each one: light, moderate or severe.
- **Bare soil:** indicate the soil percentage that remains unprotected, without plant cover, leaf litter or stones. The part of the plot taken up by rocky outcrops is excluded from this calculation.
- **Soil covered by leaf litter:** estimate the percentage of surface area that remains covered by leaf litter and other plant residue.
- **Depth of leaf litter** (in cm).
- **Rate of soil crusting:** Considerable according to the soil crust thickness and consistency when dry: light crusts tend to be less than 2 mm thick and break easily, the moderate ones tend to be 2-5 mm and the severe ones tend to be more than 5 mm and are very hard.
- **Significant presence of continuous biological crust:** indicate if there is a common or widespread presence of lichen, cyanobacteria, algae, moss etc. covering the soil. If these organisms only appear occasionally, it is not necessary to register their presence.

B) VEGETATION STATUS. The objective of this section is to establish the current state of vegetation and of other burned residues that remain in the forest. It is divided into six sections that intend to cover the maximum number of cases possible. In this way it is not always possible to fill out all the subsections (in this case, indicate in the subsection: "not applicable").

- **TOTAL COVERAGE OF LIVING VEGETATION:** estimate the percentage of the soil that the vegetation currently covers (keeping in mind all the species: arboreal, bush and herbaceous). Widespread rocky outcrop areas are excluded from this estimation.
- **POST-FIRE CANOPY REGENERATION:** for each arboreal species the following information will be noted:

- **If the species has resprouted:** way it resprouts (by stump, root, crown), density of the resprouting stumps, feasibility of resprouting (it will be less likely in the case of resprouting from the crown in which the physical stability of the trunk is compromised, than in the case of resprouting of adventitious stumps, etc.), vigour of resprouting and average height.

[12] Inventories available at www.ceam.es/Estadillos_Guia.doc

- **If the species has regenerated by seed:** density of seedlings and average height.
- In order to estimate the **density,** indicate if the stumps/seedlings are sparse (<625 units ha^{-1} the equivalent of at least one per 16 m^2), moderate (625-2500 $units^{-1}$; 2500 units ha^{-1} equivalent to one per 4 m^2), abundant (2500-5000 $units^{-1}$) or very abundant (>5000 units $^{-1}$, equivalent to more than one per 2 m^2).

- POST-FIRE REGENERATION OF SCRUBLAND

- **Total cover of resprouting scrubland:** estimate the soil percentage that bush species currently cover.
- **Total cover of scrubland with resprouting species:** estimate the soil percentage that resprouting bushes currently cover.
- **Name of the most abundant species, activity and average height of each one:** species activity means its relative abundance in respect of the whole scrub stratum, valuing it from 0 to 10.
- **Germinating species formed from highly flammable scrubland:** in the case that there are some bush species that reproduce by seed and are capable of forming nearly monospecific shrubland with an increased flammable load (for example *Ulex parviftorus* or *Cistus spp.),* estimate the density of the current existing seedlings (scarce, moderate, abundant or very abundant).

- HERBACEOUS REGENERATION

- **Total herbaceous cover:** estimate the percentage of soil that herbaceous plants currently cover.
- **Total cover from resprouting species:** estimate the percentage of soil that herbaceous plants currently cover.

Name of the most abundant species and the space each one takes up.

-OTHER OBSERVATIONS ABOUT THE STATE OF REGENERATION. Note the existence of vegetation damage caused by wildlife, cattle, humans, vehicles (except forest management, whose activities are noted in section C), etc. Note the signs of the presence of wildlife, cattle or humans that can be linked to lack of regeneration. Describe if damage is widespread or sporadic. In case that regeneration distribution follows a relevant spatial pattern, indicate it (for example seed regeneration tends not to be even, but has stains).

-SEVERELY AFFECTED VEGETATION THAT SURVIVED A FIRE. In the areas where vegetation continues to be affected by low or average severity, plants can be found that have survived from the fire (especially trees).

i. In the case of surviving trees, note the canopy cover fraction from the surviving trees Indicate the surviving tree species, the activity of each of them, the distribution of the surviving trees (extended, copses, isolated trees) and their state of development (shrub-sapling, pole, old-growth development). Estimate, if possible, the percentage of trees that have died after the fire (trees that still had green parts after the fire and have finally died). Estimate the vigour of the trees that survived the fire (recuperation of the crown, healing of infections, etc.).

ii. If signs of pests, diseases or abiotic damage are observed in the canopy that survived the fire indicate the causing agent and evaluate the impact rate; light, moderate or high, in regards to the percentage of affected trees and the level of impact on the trees attacked. For example, in the case of bark beetles: (a) light impact when holes are observed on isolated trees, without having killed the trees; (b) moderate impact when the bark beetles have caused death in recent years and they have been observed in orifices of many trees; (c) high impact when they have caused the death of many trees.

iii. In the case of surviving bushes, note the percentage of soil covered by the scrubland that survived the fire. Note the surviving species and activity of each one. Estimate, if possible, the percentage of trees that have died after the fire (trees that still had green parts after the fire and have just died). Estimate the vigour of the trees that survived the fire (recuperation of the crown, healing of infections, etc.).

- REMAINS OF BURNED TREES. Describe the burned vegetation that remains in sampling points. If remains are still in the forest but have been gathered (fascines, debris stripes, stacked together, etc.), note down the details in section C.

- Name of the plant species, estimation of the stump density, state of development, percentage of trees that have fallen, physical stability of the trees that remain standing (considering that stability will be lower if there is an imminent risk of it falling naturally).

C) POST-FIRE FOREST MANAGEMENT. Description of the forest management activities in the area after the fire, specifically noting what has been done with the remaining burned vegetation (fine and thick) and evaluating how it has affected the treatment of spontaneous vegetation regrowth from the soil surface and from the possible erosion phenomena. If possible, indicate the extension of the treatment and if it has been carried out in a widespread manner or by specific area.

SHEET 5: MONITORING POINT	*Date of sampling: ____/____/______*

POINT NUMBER:

Was this point sampled after the fire? Yes / No (If not, fill out the sampling date)

A) SOIL STATUS

Type of erosion/accumulation: Indicate severity (None Minor Moderate Severe)

Laminar erosion____________ Badlands__________________ Landslides_________________

Rills______________________ Accumulation_______________ Breakdown of walls _________

Gullies____________________ Erosion/Wind erosion________ Others_____________________

% bare soil (no vegetation, stones, leaves, burned debris) <30% 30-60% >60%

% **soil covered by leaf litter**, including burned and silvicultural debris <30% 30-60% >60%

Leaf litter layer thickness surface (<1cm) thick (1-3 cm) very thick (>3 cm)

Rate of soil crusting None Minor Moderate Severe

Significant presence of continuous **biological crust.** Yes No

B) VEGETATION STATUS

% TOTAL COVERAGE OF LIVE VEGETATION <30% 30-60% >60%

B.1. Post-fire regeneration of trees

Species	Mode of Regeneration[1]	Thickness[2]	Viability of resprouts	Strength resprouts	Height average
			high / low	high / low	
			high / low	high / low	

[1]Seed/Stump resprout/Root resprout.

B.2. Post-fire scrub regeneration

% total cover	<30% 30-60% 60%	% cover of resprouters	<30% 30-60% >60%

Species	Space occupied	Average height		Species	Space occupied	Average height

Are there any germinating species forming highly flammable scrubland?

Species	Thickness[1]

[1]Scarce (<1 sample/16 m^2); Moderate (1 sample/16 m^2-1 sample/4 m^2), abundance (1 sample/4 m^2 to 1 sample/m^2); very abundant (>1 sample/ m^2)

B.3. Herbaceous regeneration

% total cover <30% 30-60% >60%

% floor covering with resprouting species <30% 30-60% >60%

Species	Space occupied

B.4. Other remarks about the state of regeneration: damages by fauna/cattle?

SHEET 6: MONITORING POINT (continued)

POINT NUMBER:

B.5. Vegetation slightly affected which survived the fire

Canopy cover fraction of surviving trees:

There were no trees before the fire 0% <20% 20-40% 40-60% >60%

Species	Space occupied	Distribution of trees[1]	% State of development			% Mortality post-fire	Tree strength
			Sapling	Pole	Old-growth		
							high / low
							high / low

[1] Continued / Copses / Isolated trees

If there are pests, diseases or abiotic damages after the fire, assess impact level

Tree species	Agent causing mortality/weakness	Impact level
		None/Minor/Moderate/Severe
		None/Minor/Moderate/Severe

% cover by surviving scrubland 0% <30% 30-60% >60%

Species	Space occupied	% Mortality post-fire	Strength of trees
			high / low
			high / low
			high / low

B.6. Trees dead in the fire

Species	Thickness*	State of development			% of fallen trees naturally*	Physical stability of standing trees
		% Sapling	% Pole	% Old		
						high / low
						high / low

*If trees have been cut down, indicate the treatment followed in section C and leave column % of fallen trees empty

C) POST-FIRE FOREST MANAGEMENT

Has any post-fire restoration activity been performed?	Yes / No	**Which?**		
Burned timber treatment	Seeding	Planted	Hydrotechnics	Fuel control
Wall restoration	Mulch	Others.....................		

Describe action:

Describe impact (negative/positive) associated with the action:

■ RECOMMENDATIONS

Information is obtained through field sampling to carry out a diagnosis about the state of vegetation recovery. Diagnosis in early stages of regeneration will enable to assess the resilience capacities of the burned forests. Alongside the aforementioned hillside erosion control actions, this diagnosis must be oriented to future management actions. To define these alternatives, some guidelines for the decision-making process are proposed (Figure IV-1):

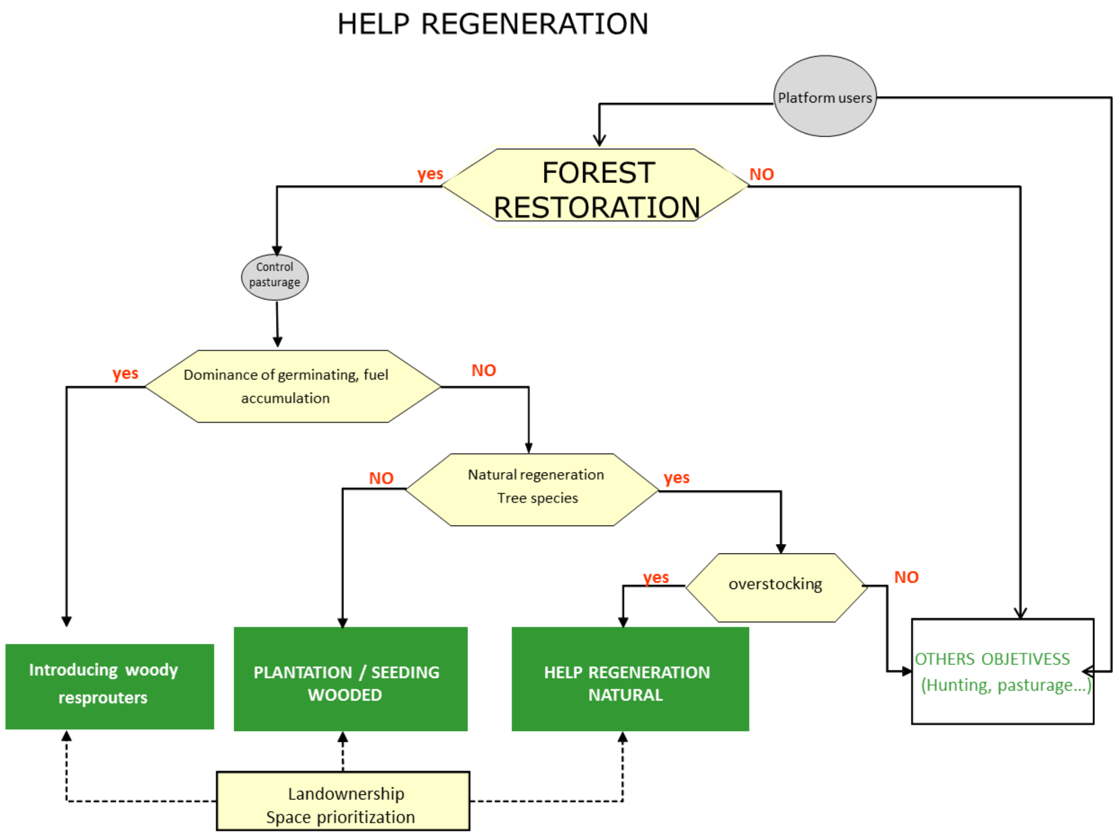

Figure IV.1 Guidance diagram for making decisions regarding the assessment of the need to apply forest restoration actions

1.- Prior to proposing any alternative, it is necessary to clearly define the goals and uses expected for the burned area. During the identification process, all social agents involved in the management, ownership and use of the involved lands should participate.

2-Nonetheless, the priority goal in the management of burned areas is forest restoration. However, under other socio-economic conditions, priority could be focused upon other goals such as pasture management, hunting or intensive timber production. The guidelines compiled in this guide are oriented toward forest restoration.

3.- One of the first actions set forth in the law is the control of grazing to avoid damages in plant restoration. This phase also enables to assess the positive role that can be played by controlled grazing and the potential economic profits that it could bring about. Under some circumstances (for example, fire walls, peri-urban areas or other areas where it can be useful for fire prevention and there is no negative impact for regenerated species), areas where pasture management could be used for fire control through cattle maintenance could be identified (considering the limits established by CAP subsidies).

4.- Diagnosis must confirm whether the regeneration process is dominated by resprouting species or germinating species, and which are the main ones. If there is a majority of germinating species, it will be necessary to increase resilience by means of repopulation actions. A sample inventory to identify the areas to be potentially repopulated in a burned area is available in TRAGSA (2009).

5.- In this phase, another criterion that could justify the recommendation of repopulation is the absence of regeneration among tree species.

6.- Under other circumstances, excessive regeneration could occur and clearing activities will be required to reduce intraspecific competence (helping regeneration) and lower the fuel load (Moya et al., 2009; De las Heras et al., 2012). Silviculture treatments applied at ages 6-7 after the fire in naturally regenerated areas of *Pinus halepensis* are a highly useful tool to increase plant biodiversity, accelerate reproductive maturity and increase resilience within these forests (Moya et al., 2009). Similar results are found for *Pinus pinaster*, where early and intense clearing (5 years) has proven effective for the management of the regeneration of highly serotinous ecotypes. 2011). As for resprouting species, in order to improve post-fire regenerated areas, coppice at ages 10-12 is performed so as to reduce competence, enhance sexual reproduction and expedite development toward sapling phase (Serrada et al., 2008, 2012; Sánchez-Humames & Espelta, 2011).

Figure IV.2 Regenerated area from a fire with Aleppo pines of over 15 years of age. The necessary treatment to reduce thickness and allow the evolution of the forest is long overdue.

7.- Once the forest restoration actions have been identified, these can be complemented with actions oriented toward other goals: hunting actions (Bellido et al., 2013), planting mycorrhizal plants with commercially valuable fungi in firewall areas (Reyna & Garcia, 2005),...

In Moreira et al. (2012) and http://uaeco.biol.uoa.gr/cost, there is information about the main restoration actions in burned areas applied in Southern Europe.

■ Application Example

The medium-term assessment method was also applied to analyse, 18 months after the fire, the evolution of post-fire regeneration described in the above section *(Addendum I:* Application of the assessment protocol to the Vall d'Albaida fire of 2010).

In this diagnosis, the level of development of vegetation 18 months after the fire was assessed, alongside the factors that affected its growth and the potential actions to be developed in order to encourage ecosystem recovery. In addition, monitoring activities have allowed to delve into the ecological effects of the fire and of the risk prevention and restoration actions that have been conducted, as well as confirming on-site the forecasts and the information provided in the fire emergency report.

Using this methodology, visits have been made to the areas sampled during emergency inspection, where observation and assessment points have proceeded to include areas where burned wood treatment actions have been conducted along with other areas that present particularities or specific risks.

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LONG-TERM ASSESSMENT OF BURNED AREAS

■ INTRODUCTION

Some years after the fire, the identification of its impact can be conducted through several approaches depending on the goals sought with the assessment. These goals could be, among others: to assess vegetation cover, composition and structure levels; to assess the effectiveness of the actions conducted after the fire; to measure biomass accumulation, etc., all of which are criteria that could easily be included in management plans.

Over time, the impact of other events such as droughts or pests, as well as the impact arising out of forest management activities can add to the impact of fire. In addition, for fires that took place many years ago, there can be a lack of specific information about the vegetation before the fire, which makes the interpretation of post-fire evolution more difficult. All these factors make the assessment process more complex. On the other hand, some of the difficulties that affected both short-term and medium-term assessments still apply: heterogeneous spaces and available resources.

In spite of the wide range of objectives and affected areas, long-term assessments mainly focus on analysing the recovery status and the functionality of the ecosystems affected by the fire, that is to say, the capacity of the forest to generate goods and services (see *Millennium Ecosystem Assessment* 2005; http://www.wri.org/publication/millennium-ecosystem-assessment). As a result, the assessment must at least depict the recuperation status of the ecosystem affected by the fire, its resilience against disturbances (in this case, fires), fuel accumulation levels (as a risk indicator of new fires) and the level of protection and functionality of the soil (as an indicator of the conservation level of the soil). Alongside these considerations, the specific circumstances of each fire may require specific indicators on the viability of special species, other exploitations, etc.

■ METHODOLOGY

Many different approaches and methodologies can be applied at this point depending on the goals and available resources for the assessment. In any case, this is a complex process that requires a significant information flow and much time.

Possibly, one of the most archetypal long-term assessments of fires is that conducted further to the large Yellowstone fires of 1988 (Wallance, 2004). In this context, Romme & Turner (2004) propose an assessment framework based on the following criteria: analysis of the disturbance regime (disturbances being fires in this case), structural analysis (both at a forest stand and landscape levels), identification of endangered species as a result of fires, structural recovery, composition and functionality of affected ecosystems and identification of unexpected harmful impact.

Another example of long-term assessment of a burned area, this one being somewhat closer to our case, would be the GEORANGE project (www.georange.net; Róder et al., 2002). In spite of its clear scientific approach, this project has closely monitored the regeneration of a burned area using remote sensing (Figure V-1) and extensive field sampling. In addition, the spatial analysis of the distribution of fuel models and the simulation of fire spreading (Figure V-2) has enabled the definition of criteria to design preventive and fire suppression infrastructures (Duguy et al., 2013, 2007).

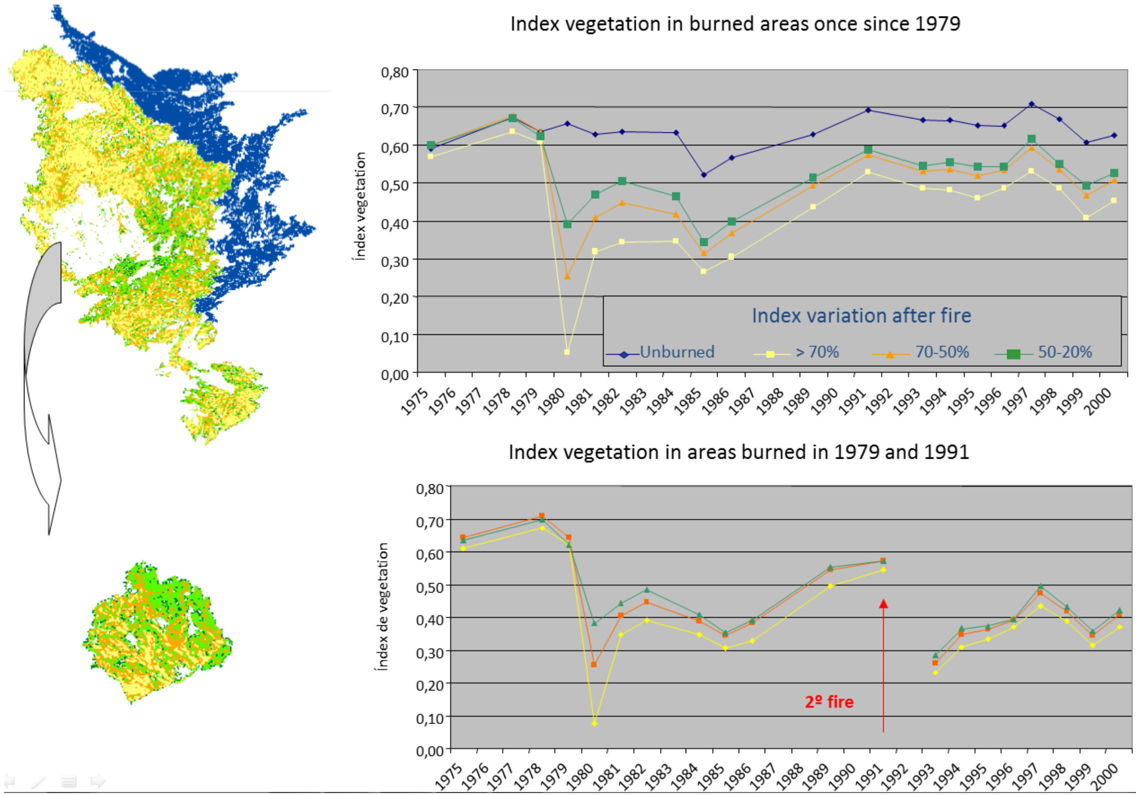


Figure V-1. Evolution of natural regeneration on the forest surface affected by the Ayora fire in 1979, analysed as per a vegetation index obtained through Landsat images during the 1975-2001 period. Top: burned surface once since 1979. Bottom: burned surface in 1979 and 1991.

In our case, the assessment can be conducted as per indicators regarding cover levels and functional features of vegetation (particularly its resprouting capacities), the spatial proportion and structure of soil free of vegetation (erodible soil) and its functional status (nutrient penetration and retention). An example of the application of these indicators is the PRACTICE project *(Prevention and Restoration Actions to Combat Desertification;* http://practice-netweb.eu).

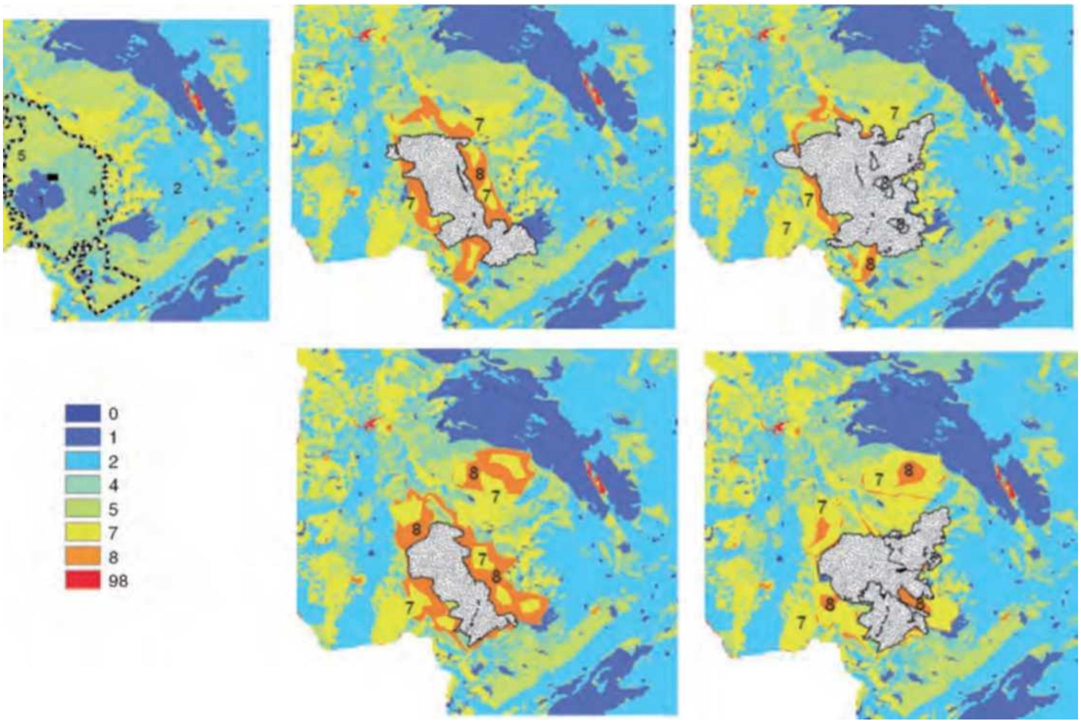


Figure V-2. Simulation of fire spreading in different scenarios of fuel distribution (as per Duguy et al., 2007). The image at the left top depicts the perimeter of the great Ayora fire of 1979 (black dotted line). The remaining pictures show the result of the simulation of said fire under the same climate conditions as in 1979 under several fuel model distribution and firewall area scenarios. The colour ranges and numbers on the pictures depict fuel models (98 corresponds to non-forest surfaces). The best combination of prevention techniques (the image at the left bottom) could help reduce the burned area by more than 50% in respect of the fire of 1979 under extreme meteorological conditions.

Figure V-3. Firewall area from which a fire front was controlled (Chelva 2012, Valencia).

PRACTICE is a project included within the Seventh Framework Programme of the European Commission which has developed specific methods to assess management options in areas exposed to desertification risks. Common indicators in the project have been agreed in order to describe ecosystem services for raw material supply, regulation and maintenance of the system. Considering the main agent causing desertification, common indicators are complemented by other specific indicators for a particular context. As a result, 13 indicators have been selected to analyse burned areas: water conservation, soil conservation, soil quality, biodiversity, forest health, biomass/carbon sequestration, fire risk, productive value, recreational and tourist uses, aesthetic value, cultural value, influence in home economics and the economic cost of the action.

The necessary samplings for data collection can be approached as per different alternatives or methods: field inspections similar to those described in previous stages, complemented with field work or information available (for example, plots in the Forest Inventory); remote sensing information (Roeder et al., 2008; San-Miguel et al., 2011) and LIDAR (Van et al., 2013); adaptations to other methods, such as the assessment forms of the REACTION projects (Restoration Actions to Combat Desertification in the Northern Mediterranean;http://www.ceam.es/ ; Bautista y Alloza, 2009), Cost Action FP0701 (Post-Fire Forest Management in Southern Europe; http://uaeco.biol.uoa.gr/cost) or the aforementioned PRACTICE project (an example of this application is explained later on in this document). Each situation will require the adaptation of the method to local information, budgetary and time-related conditions.

■ RECOMMENDATIONS

At this point, the information collected from the sampling process must be interpreted according to the landscape and with some previously defined goals. In our framework, the goals focus on forest restoration, but priorities should be defined by the needs and preferences of the social agents of each area. Taking these considerations into account, restoration activities will be justified if there is an absence of species that are representative of mature succession stages or low biodiversity, both factors reinforced by the need to prevent new fires and to promote resilience (Figure V-4).

Moreover, the time range allows for checking whether regeneration is developing according to the self-succession process or whether there have been any exceptions either in shrubland communities (Bazla et al., 2007) and in trees (Retana et al., 2002). Alongside the evolutionary criterion, the interactions of the fires with the landscape (Moreira et al., 2012) and fuel (Duguy et al., 2007 & 2013) will determine whether actions need to be carried out. In the case of afforestation, these actions will basically focus on planting woody species, mainly resprouting species (and mostly deciduous species in the case of trees) and combinations of conifers and deciduous species. In situations where dense scrubland is dominant with a high concentration of fuel at risk, clearings actions can be conducted through grinding and surface distribution of debris as mulch (Baeza et al., 2005).

In order to guarantee maximum plantation success, species selection must be carried out keeping in mind their bioclimatology and autoecology, considering the implications of climate change forecasts upon the fire regime (Loepfe et al., 2012), as well as upon species adaptation (Crowe & Parker, 2008; Stephens et al. 2010). Furthermore, spatial distribution of species must be carried out by geomorphological units and with spatial prioritisation as a criterion (amongst which soil property will have to be considered). All criteria must lead to the correct design and execution of the plantations (Serrada et al., 2005) and a subsequent follow-up of the results.

Once the diagnostic and formulation of the restoration alternatives are complete, the process can continue with actions to cover other goals (landscape, recreational, hunting, CO_2...), not only focusing on the forest perspective, in order to integrate actions in the agricultural and urban interface.

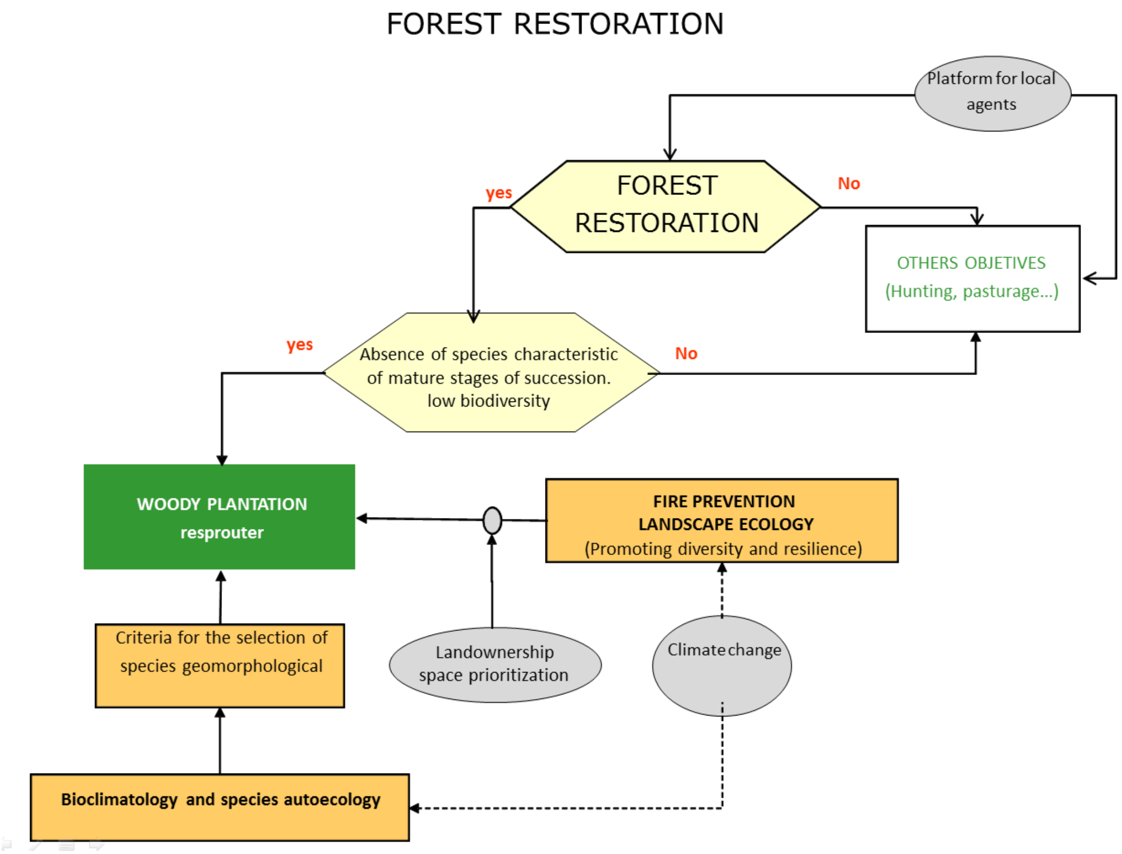


Figure V-4. Decision-making support scheme in order to evaluate forest restoration actions.

In the decision-making process (Figure V-4) it becomes increasingly necessary to count on mechanisms for civil participation. However, this participation must be organised so it is not subordinate to technical considerations. Furthermore, considering that not all forests grow back the same after wildfire, in specific situations participation can help when considering new alternatives and determining the final direction of the restoration.

■ Application Example

In the framework of the PRACTICE project (http://practice-netweb.eu), a European project coordinated by the CEAM Foundation, an assessment was conducted of the state of regeneration of vegetation in the burned area after the Ayora fire in 1979 (nearly 30,000 ha burned).

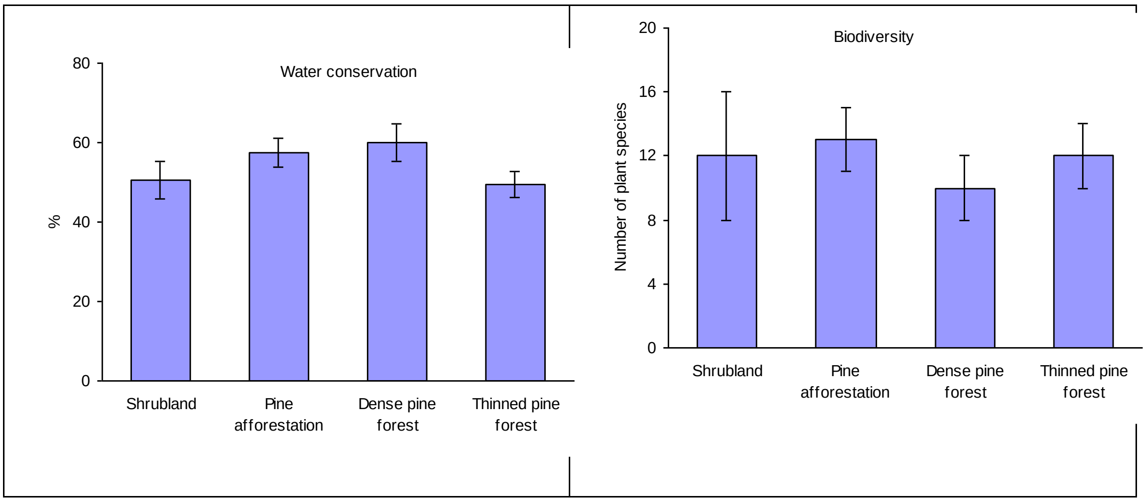
In order to evaluate the process, the 4 management alternatives that were most representative of the area were selected. These considerations were: scrubs regenerated after the fire (considered in the study as an example of non-intervention), reafforestation with pine trees (mainly carried out at the beginning of the 1990s), natural regeneration of Aleppo pine forests spontaneously developed after the fire (considered as non-intervention) and the natural regeneration of pine subject to subsequent forest clearing (mainly carried out at the beginning of the 1990s).

In addition, information was obtained about the 13 selected indicators (water conservation, soil conservation, soil quality, biodiversity, forest health, biomass/carbon sequestration, fire risk, productive value, recreational and tourist use, aesthetic value, cultural value, influence in home economics and the economic cost of the action).

In this case, the methodology applied is based on the Landscape Function Analysis (LFA; Tongway & Hindley, 2004). The LFA methodology allows the proportion and distribution of patches of bare soil (or vegetation) and in its functional state to be evaluated in a relatively simple and standardised way. In this way water conservation can be measured from the infiltration index set out in the *Landscape Function Analysis* (LFA, Tongway & Hindley, 2004). In order to estimate soil conservation, the stability index in the LFA will be weighed against the vegetation cover (estimated based on transects). Soil quality was estimated by weighing the nutrient cycling index of the LFA against the percentage of organic matter on the soil (Nelson & Sommers, 1996). Biodiversity (species richness) is estimated according to the number of vascular species found in vegetation transects. In order to calculate the biomass/carbon sequestration estimation, the above-ground biomass of vegetation (using allometric equations that establish the relationship between the basal diameter and dry biomass and considering that 50% of this biomass is carbon) and the quantity of organic carbon in the soil were aggregated. In order to calculate fire risk, an estimate of the intensity of a forest fire under standard climate conditions was carried out, keeping in mind the fuel model and accumulated biomass (MAPA, 1987; Vélez, 2000). As for forest health, pest risks, especially bark beetles, were considered. For this purpose the opinion of experts from autonomic administration bodies was taken into consideration. The economic cost of actions was estimated based on the estimated budgets provided by companies in the sector. Results are set out in Figure V-5:

The integration of the marked indicators was carried out through the multi-criteria decision analysis (MCDA) based on Roy & Bertier (1973) with the statistic software ELECTRE. To sum up, this method measures the intensity of the statement that "management option A is at least as good as option B" between pairs of actions. It combines two analyses: one assesses how many indicators support the statement and the other assesses the magnitude of the differences between each pair of management options with regard to the values of the considered indicators.

The multi-criteria analysis of the indicators and actions showed that the best management option was the natural regeneration of pine trees through forest clearing, the second action was reafforestation, whilst scrubland and natural pine regeneration without any intervention had the lowest ratings (Figure V-6).



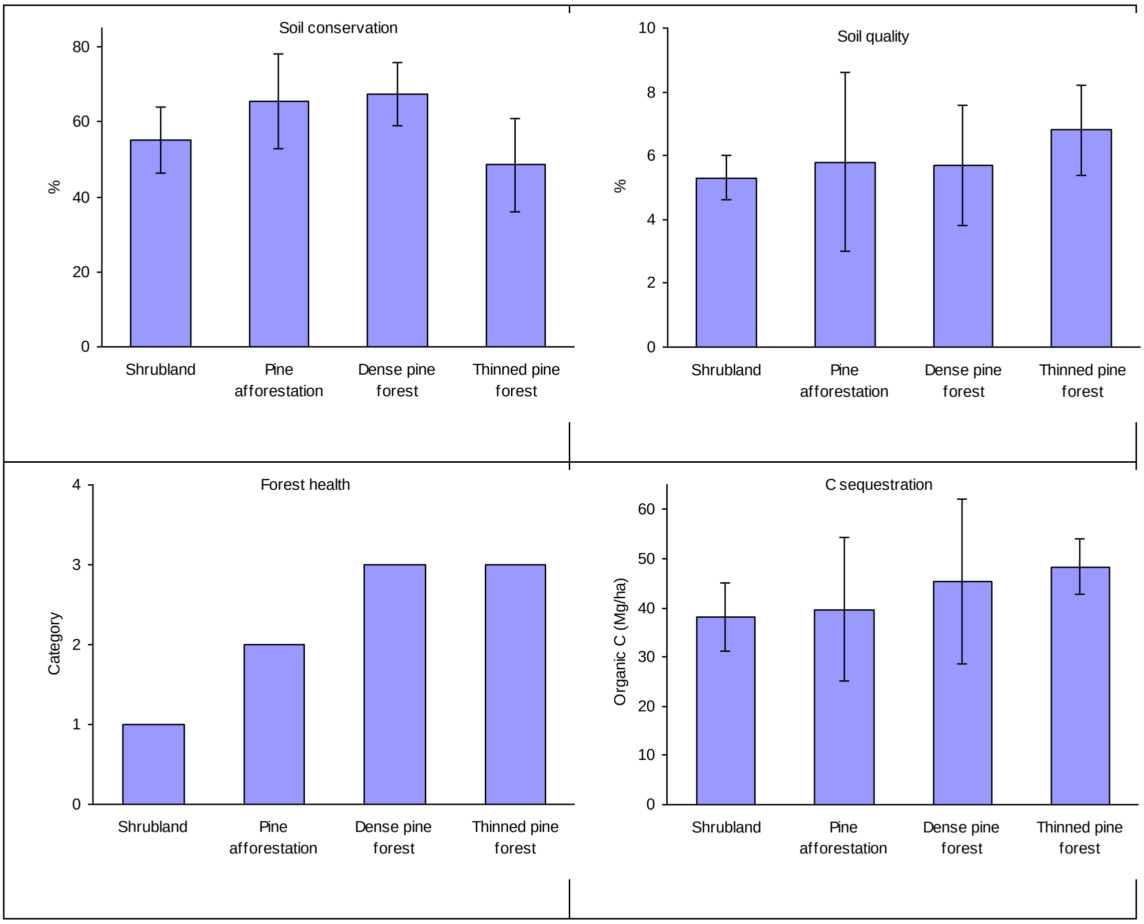


Figure V-5a. Estimated values of some of the indicators considered in the analysis of management options carried out in the Ayora area. Average values and standard deviations.

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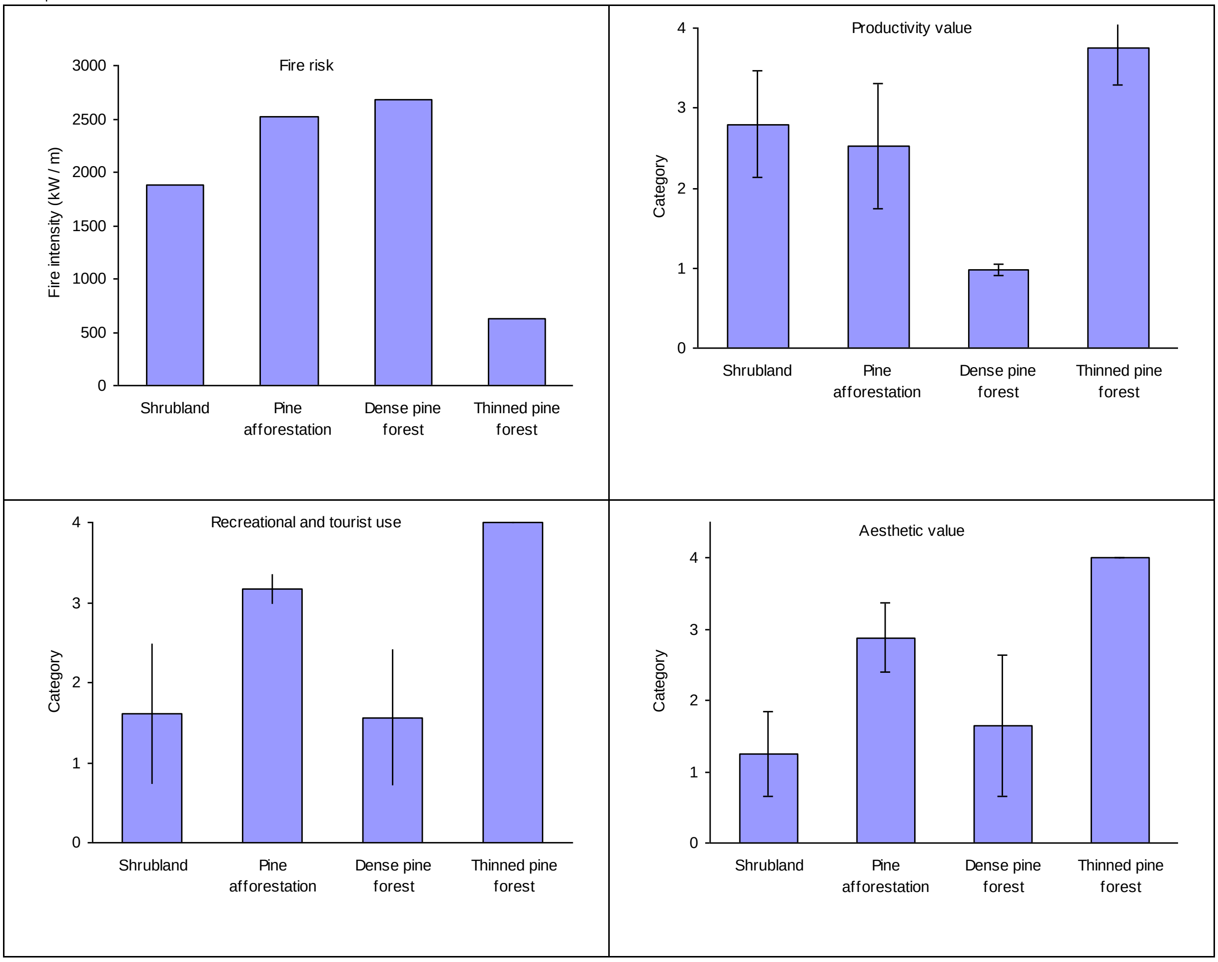
Fire risk
Fire intensity (kW / m)
3000
2500
2000
1500
1000
500
0
Shrubland
Pine afforestation
Dense pine forest
Thinned pine forest
Productivity value
Category
4
3
2
1
0
Shrubland
Pine afforestation
Dense pine forest
Thinned pine forest
Recreational and tourist use
Category
4
3
2
1
0
Shrubland
Pine afforestation
Dense pine forest
Thinned pine forest
Aesthetic value
Category
4
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2
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Shrubland
Pine afforestation
Dense pine forest
Thinned pine forest

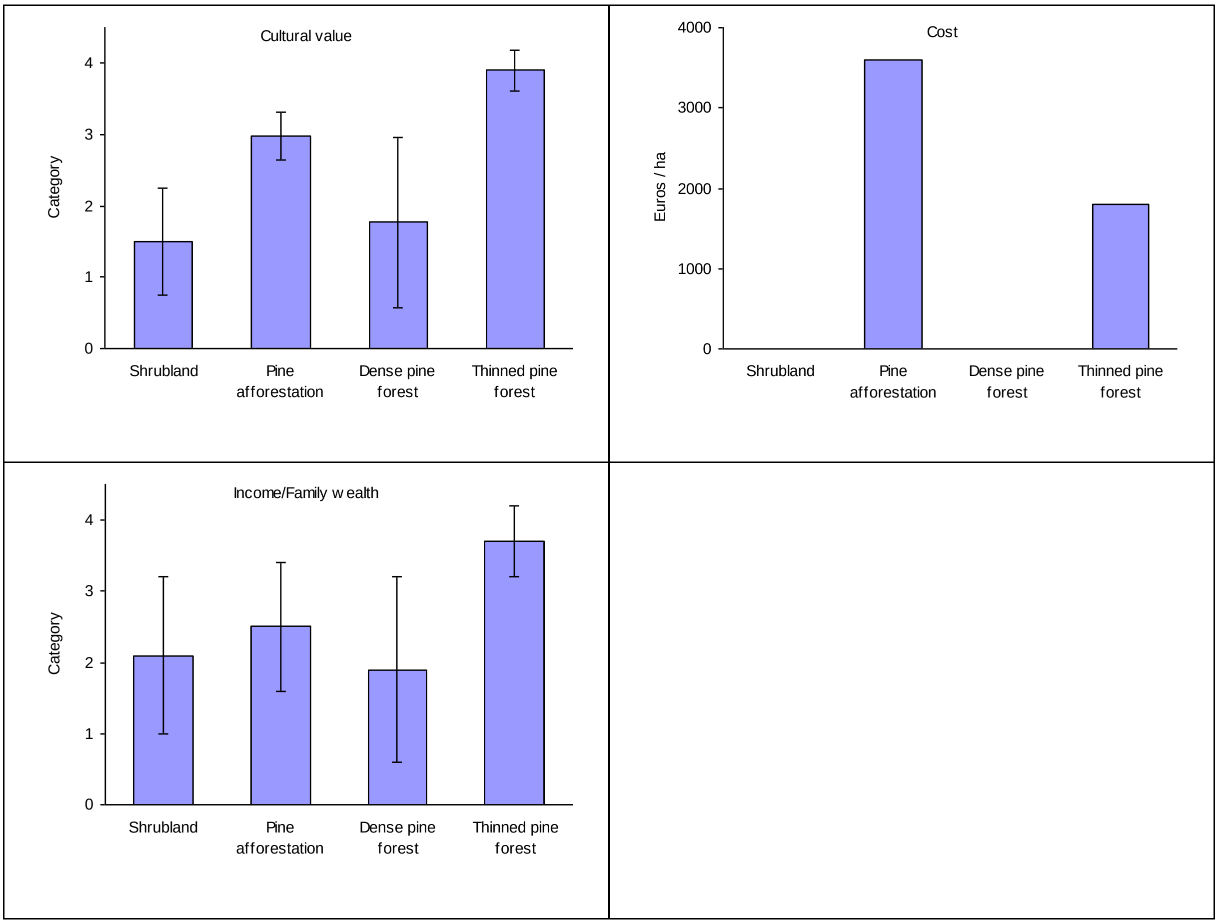

Figure V-5b. Estimated values of some of the indicators considered in the analysis of management options carried out in the Ayora area. Average values and standard deviation.

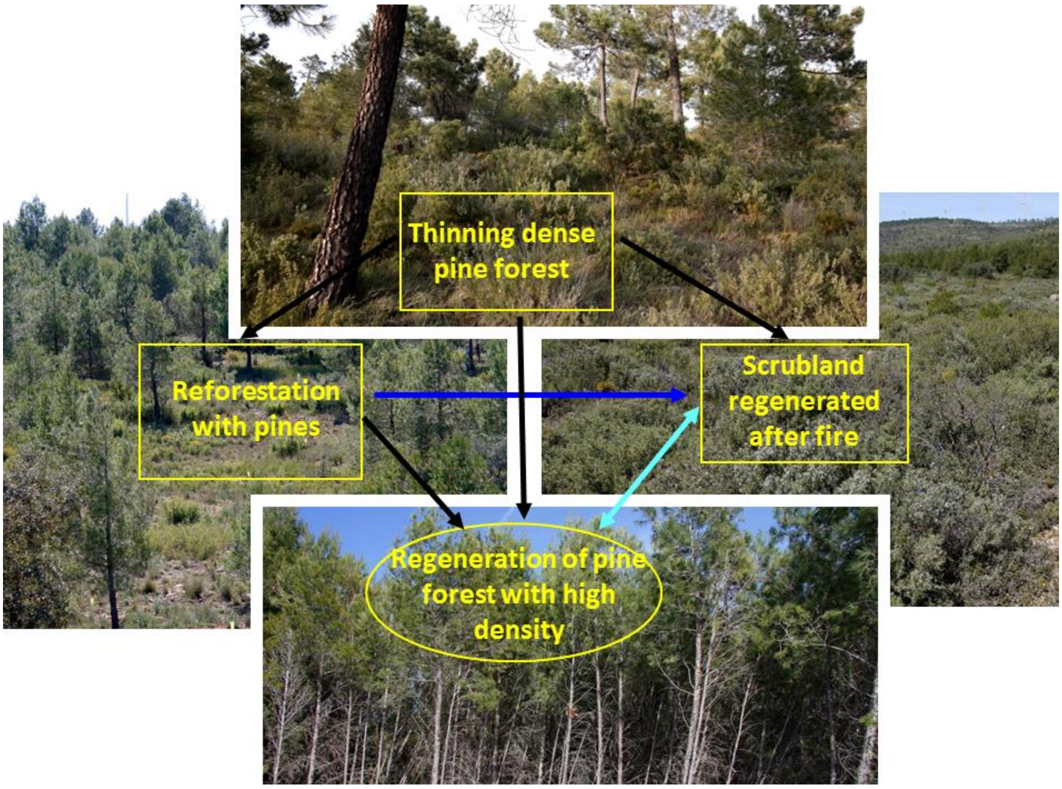

Figure V-6. Results of multi-criteria analysis considering the four management options under assessment. The direction of the arrows indicates highest to lowest ratings between option pairs.

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ANNEX I: APPLICATION OF THE ASSESSMENT PROTOCOL TO THE FIRE OF VALL D'ALBAIDA (VALENCIA) 2010

■ INTRODUCTION

In order to verify the applicability of the conceptual framework and the assessment methodology, each of the steps applied to a real case has been described in this text. To be precise, the example to which the method has been applied is a 3,000 fire ha which in September 2010 affected different municipalities in the South of Valencia and the North of Alicante. The information described herein is a summary of the *Informe urgente sobre el impacto del incendio forestal de Bocairent-Agullent de septiembre de 2010* (Emergency report on the impact of the forest fire of Bocairent-Agullent of September 2010) (Gimeno et al., 2010) and the *Informe Impacto del incendio forestal de Bocairent - Agullent de septiembre de 2010. 2ª fase: evaluación a los 18 meses (Report on the impact of the forest fire of Bocairent - Agullent of September 2010. 2nd phase: assessment 18 months later)*(Garcia et al., 2012), both drafted for the Regional Ministry of Infrastructures, Land and the Environment of the Autonomous Community of Valencia.

As described in the methodology, the ecological impact has been assessed by means of systematic sampling processes and visits to the burned area, gathering cartographic information and consulting local information sources. In addition to assessing the fire's immediate impact, monitoring and assessment of burned wood management and of the evolution of the vegetation cover 18 months after the fire have been conducted.

Figure 1. Picture of the fire in the vicinity of one of the affected municipalities. Picture taken 10 days after the fire

■ PRELIMINARY DAMAGE ASSESSMENT. IDENTIFICATION OF THE POTENTIALLY VULNERABLE AREAS ON A PLANNING SCALE.

In this section, the potentially vulnerable areas are identified based on the cartographic information available and applying the criteria described in section II of the Guide within the perimeter of the fire.

With the applied criteria, the expected regeneration in the area affected by the fire is high since scrubland prevails (Figure 2). Regarding erosion, the values of the potential erosion cartography are high (Figure 3). According to the RUSLE model, more than 96% of the area is at a high or very high risk of potential erosion, a situation which does not match the research conducted on the field.

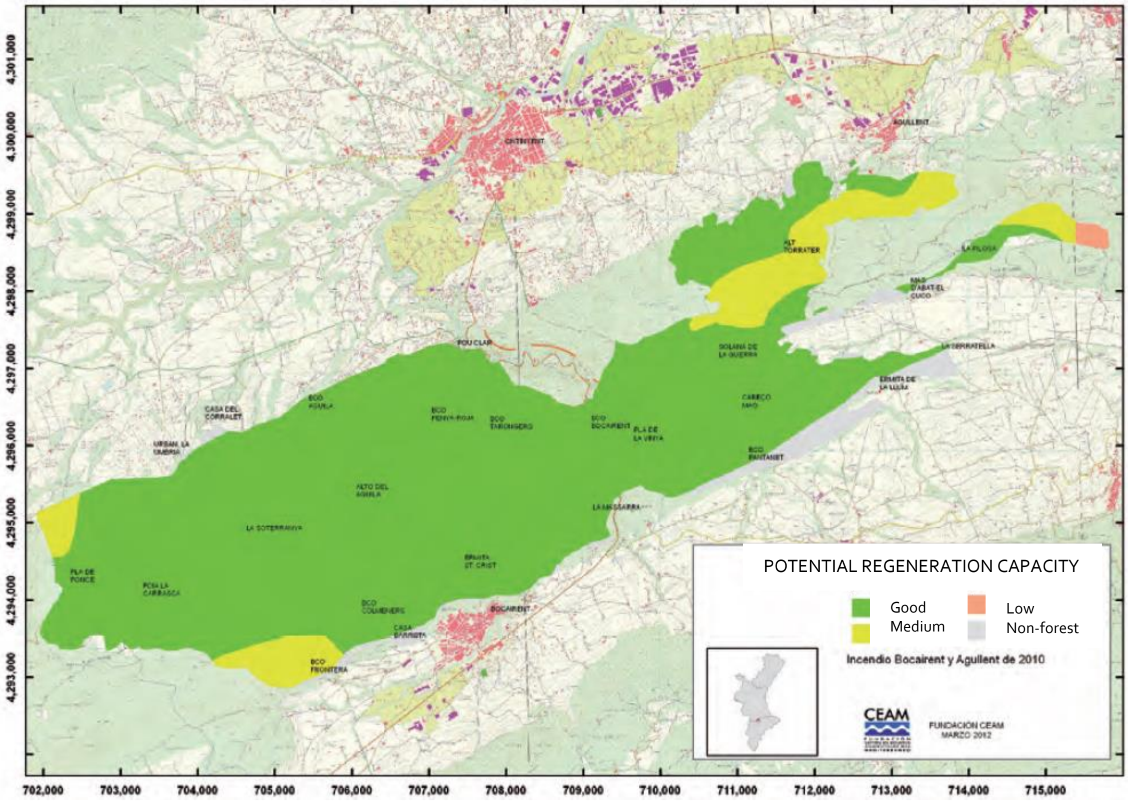

Figure 2. Expected regeneration within the perimeter of the fire, according to the cartographic information (as a result of incorporating the intrinsic self-succession capacity and the speed of regeneration). Green: good. Yellow: medium. Reddish: low. Grey: non-forest.

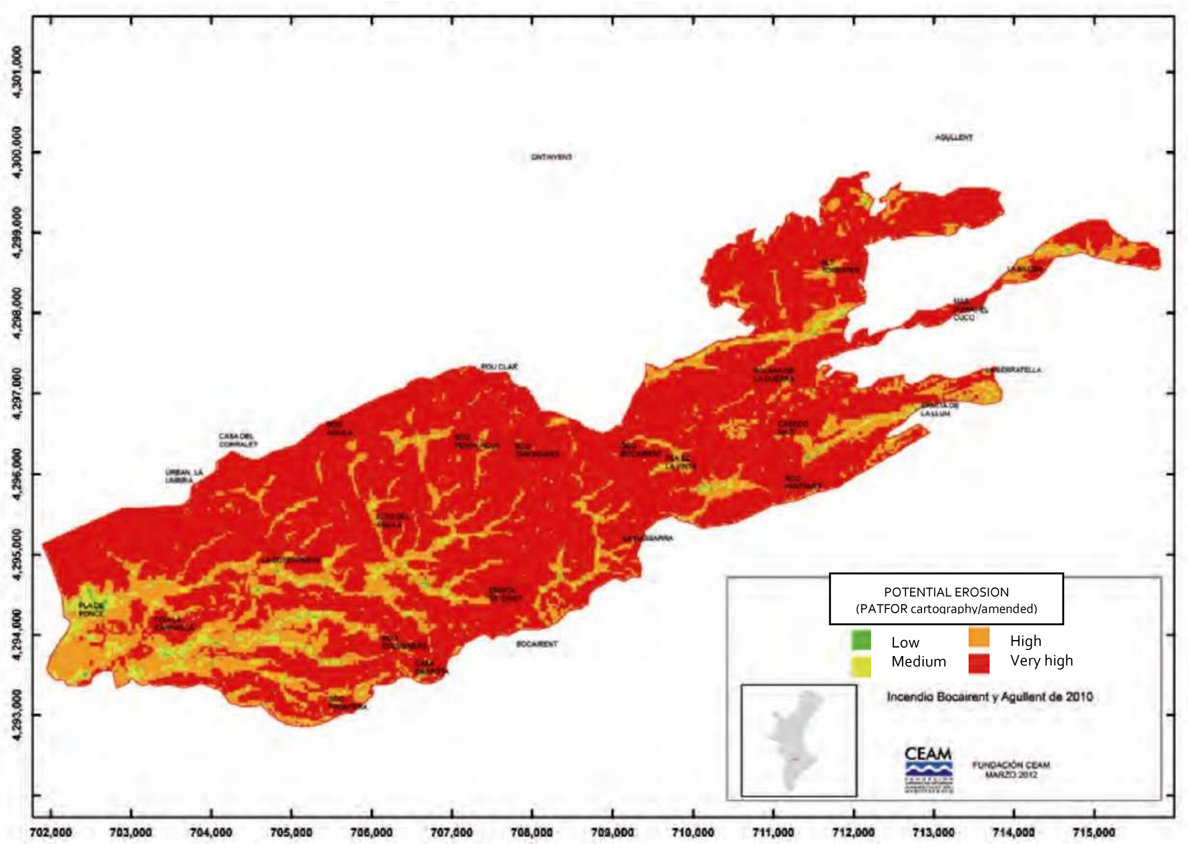

Figure 3. Original potential erosion (PATFOR Cartography). Green: low. Yellow: medium. Orange: high. Red: very high.

The estimation of soil losses indicated by the USLE application and its derivative models is usually oversized (Sánchez, 1997), especially in the most permeable soils. For this reason, in the assessment methodology the potential risk is reduced to the lowest scale in those soils located on limestone or dolomite outcrops (Lepart & Debussche, 1992); as a result, the risk levels are substantially reduced (Figure 4).

The cartographic integration of the potential regeneration capacity and the erosion risk results in more than 80% of the area having a low potential vulnerability (Figure 5).

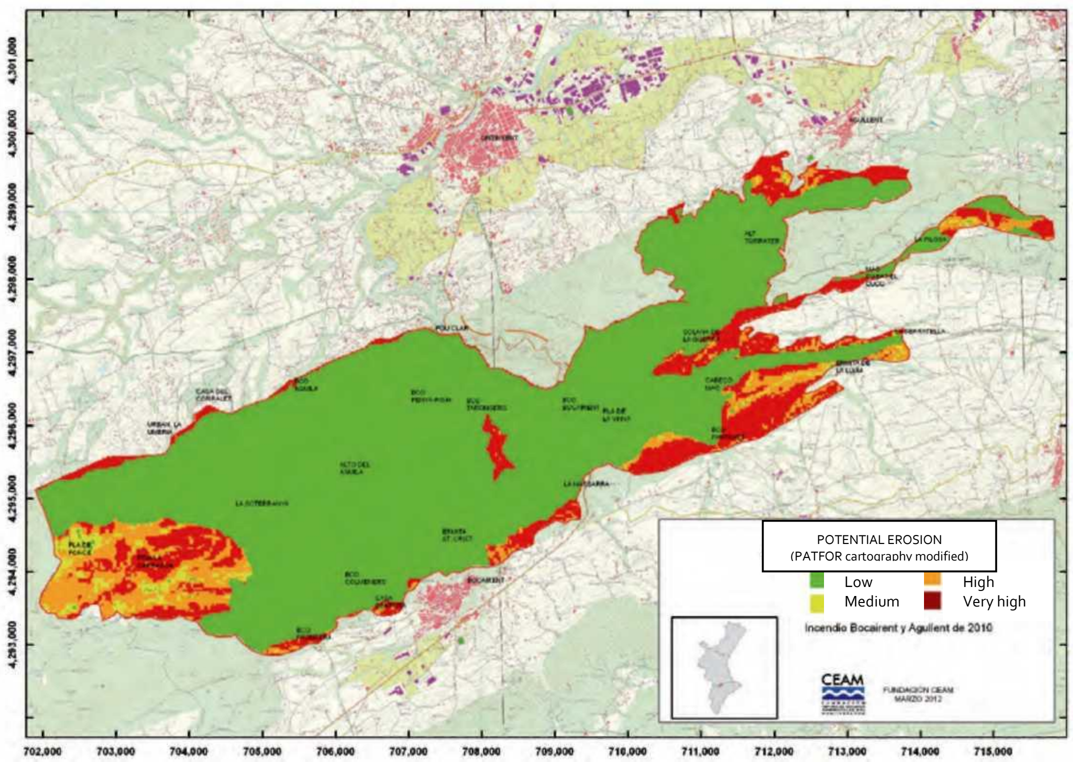

Figure 4. Potential erosion (PATFOR cartography modified by lithology). Key: Green: low. Yellow: medium. Orange: high. Red: very high.

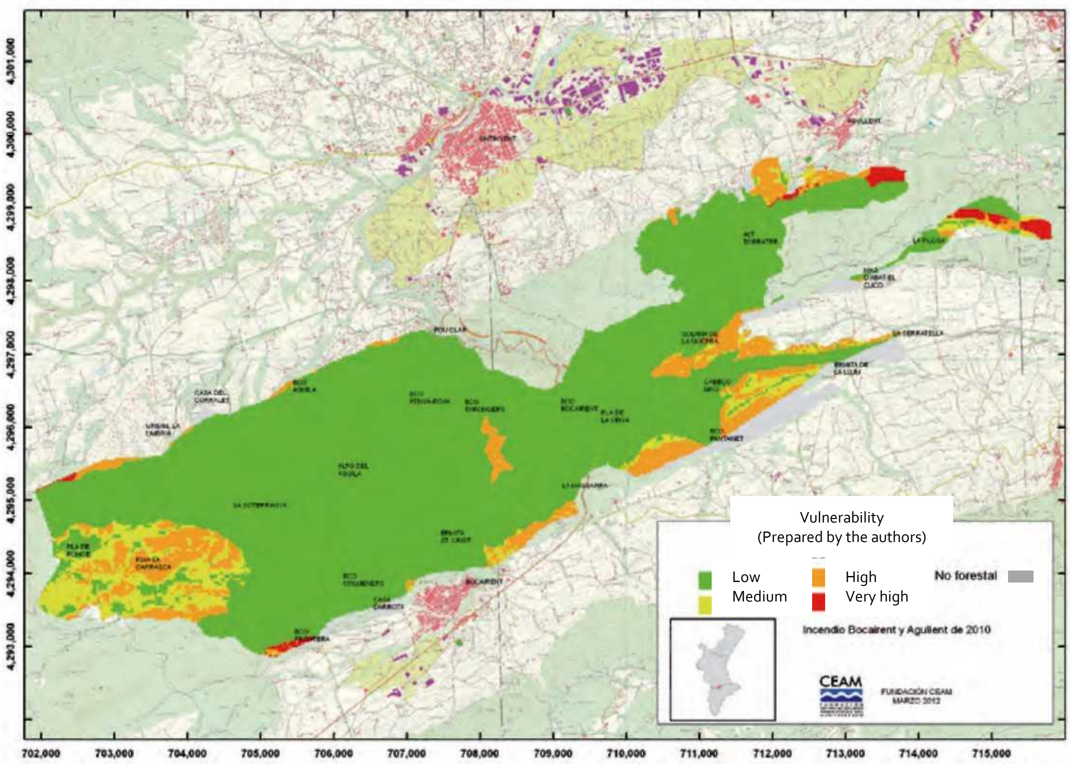

Figure 5. Vulnerability (as a result of merging the expected regeneration with the erosion risk) Key: Green: low. Yellow: medium. Orange: high. Red: very high.

■ EMERGENCY ASSESSMENT

1. DOCUMENTATION: CHARACTERISATION OF THE BURNED AREA

In this section, the main characteristics of the burned area are summarized:

1.1. Affected area

The burned area is located at the inland mountain ranges of the Autonomous Community of Valencia, between the provinces of Valencia and Alicante. According to the data of the Regional Ministry of Infrastructures, Land and the Environment of the Autonomous Community of Valencia, the forest area affected by the fire was 2,984 ha. The fire basically affected forest areas, with very few crop land enclaves or plots, but with a significant impact upon the urban-forest interface (urban area of Bocairent and Agullent, semi-urban area in Bocairent, Agullent and Ontinyent).

The fire affected a part of the Site of Community Interest (SCI) *Serres de Mariola i el Carrascal de la Font Roja*. This area, which was burned in the fire, was 329 ha (less than 2% of the total area of the SCI).

Chart 1. Area (according to cartography).

Fire date	06/09/2010
Municipalities affected	Ontinyent, Bocairent, Alfafara, Agullent, Agres, Albaida, Benissoda
Forest area affected	3,160 ha (non-official area, taken from cartography), 84% of the area was unforested and mainly private (Figure 6)
Protected areas	SCI Serres de Mariola (329 ha burned)
Fire recurrence between 1979-2010	60% of the area burned twice (including the fire in 2010) 40% of the area burned 3 times (including the fire in 2010) Figure 7

1.2. Fire recurrence

The perimeter of the current fire has burned on several occasions in the past: in 1979 there were two fires, in the 1980s there were three fires in the North and North-East area and in 1994 virtually the whole area of the affected space was burned. Since the mid-1990s and until last year, there were many small fires (less than 1 ha) on the current burned area.

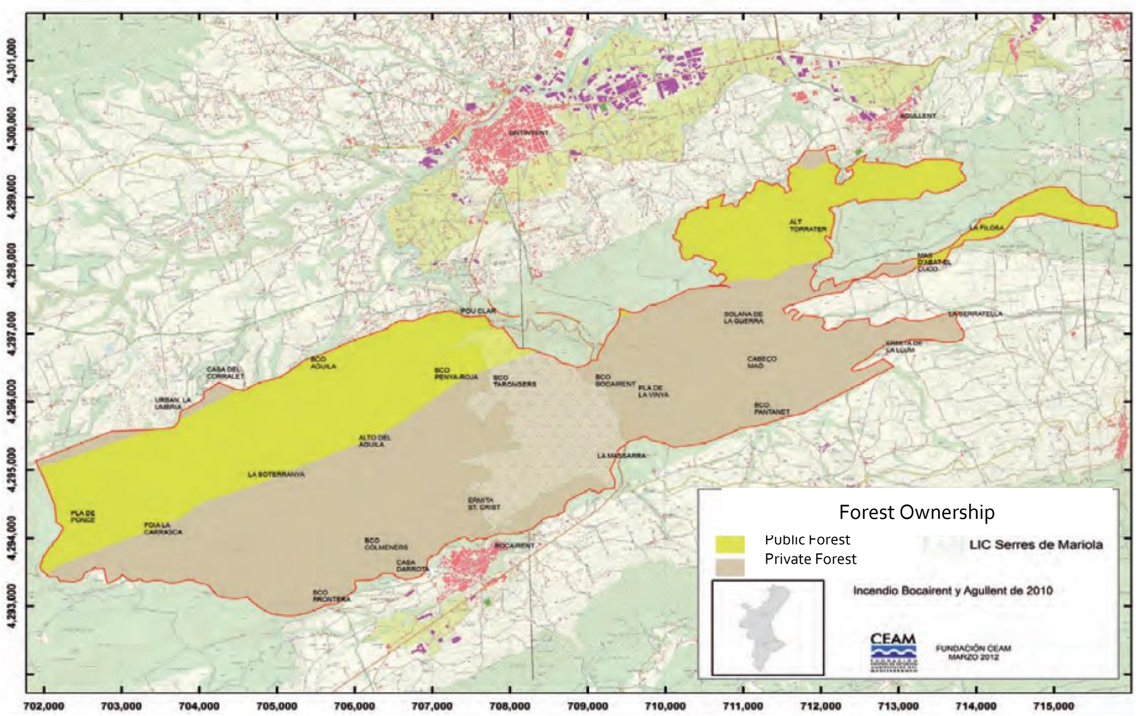

Figure 6. Perimeter of the fire and mapping of forest ownership status. Key: Green: public forests. Brown: private forests. Section highlighted on ochre: SCI Serres de Mariola

1.3. Climatology

According to Pérez-Cuevas (1994), the average annual temperature in the burned area is around 15°C, the average temperature in the hottest month about 24°C and the average annual precipitation is 600 mm.

Chart 2. Bioclimatic parameters

Thermoclimate	Mesomediterranean
Ombroclimate	Dry sub-humid
Potential vegetation	*Bupleuro rigidi* and *Quercetum rotundifoliae* Mesomediterranean basophilic groves, typical and thermophilic faciations with *P. lentiscus*

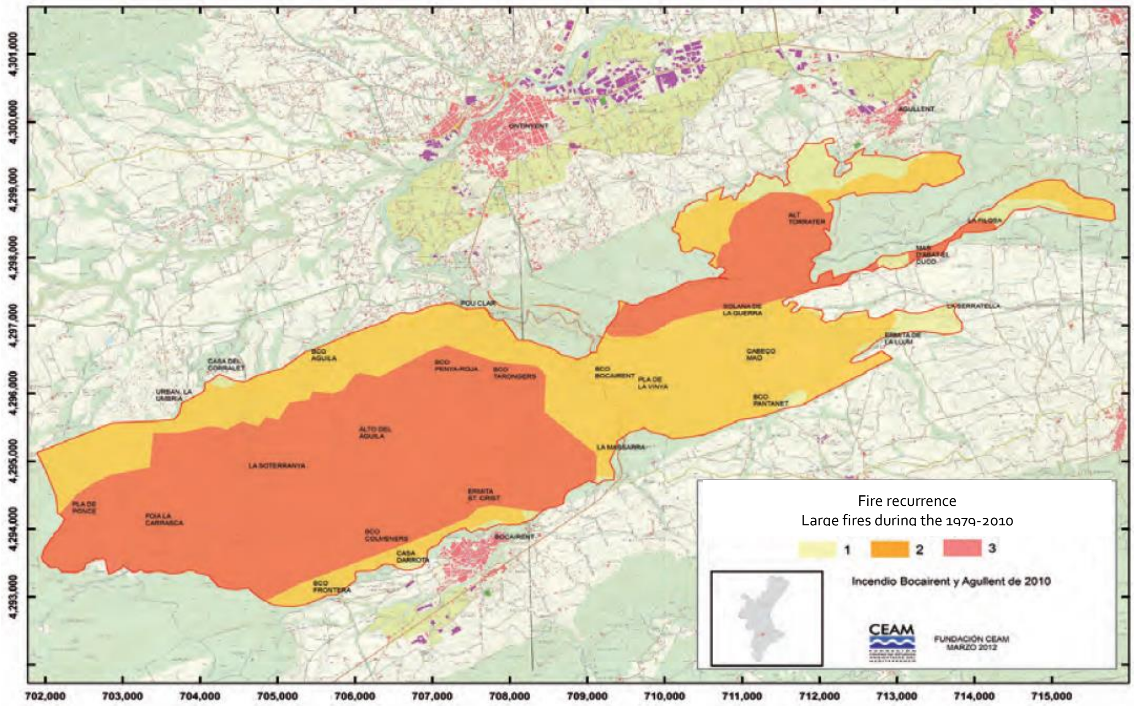

Figure 7. Fire recurrence. Number of large fires between 1979 and 2010. Key: Red: 3; Orange: 2; Yellow: 1.

1.4. Lithology

The dominant lithology comprises cretaceous limestones (taking up approximately 85% of the affected area).

Chart 3. Lithology types

Geological substratum	Distribution over the burned area (Figure 8)
Biological and sandy limestones (with layers of pure limestones and marly limestones)	Main lithology, present in 85% of the area: axis of the whole burned mountain range.
Dolomites or marly dolomites (occasionally Quaternary red clays)	Distributed over 10% of the area, toward the W end (Pla de Ponce, Foia de la Carrasca)
Tertiary marls (occasionally Quaternary colluvium, sandstones and clays)	Represented by 5%: North and South piedmont in the municipality of Alfafara up to middle-slope areas.

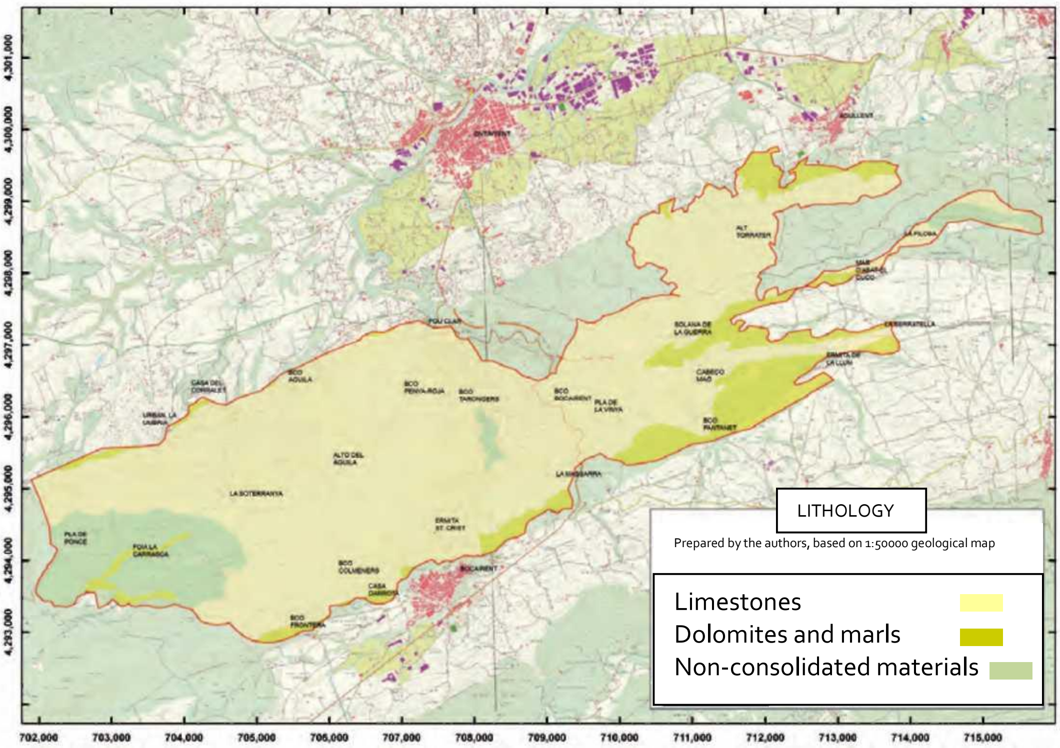

Figure 8. Lithology distribution. Key: Yellow: limestones. Light green: dolomites and marls. Deep green: non-consolidated materials.

1.5. Affected vegetation

The wooded area exclusively comprised *Pinus halepensis* pine forests. Due to the high fire recurrence, the area of these pine forests has been highly reduced compared to that in the 1970s. Therefore, before the fire of 2010, pine forests comprised patches of wooded areas which were not affected by the previous fires, forest stands regenerated after the fires of 1979 and young pine forests regenerated after the fire of 1994.

Before 2010 pine forests took up around 15% of the area affected by the fire (Figure 9). Mature pine forests had, in general, medium-high thickness. Underbrush was scarce, with presence of kermes oak, rosemary, mastic tree, Mediterranean buckthorn, rockrose and some patches of holm oak shrub, with Mediterranean false brome prevailing in the herbaceous stratum. The patches of young pine forest were not, in general, very extensive (less than 1 ha); some of them were on abandoned crops and others on areas burned in 1994, and with a very diverse thickness.

The remaining 85% of the area was taken up by scrubland, which had relatively homogeneous characteristics in the whole area. In general, rosemary, rockrose, heather and cade. In Pla de Ponce and Solana de la Filosa regions, the presence and size of kermes oak, cade and holm oak increases. In other areas the presence of gorse *(Ulex parviftorus)* increases, although dense areas of gorse only existed occasionally.

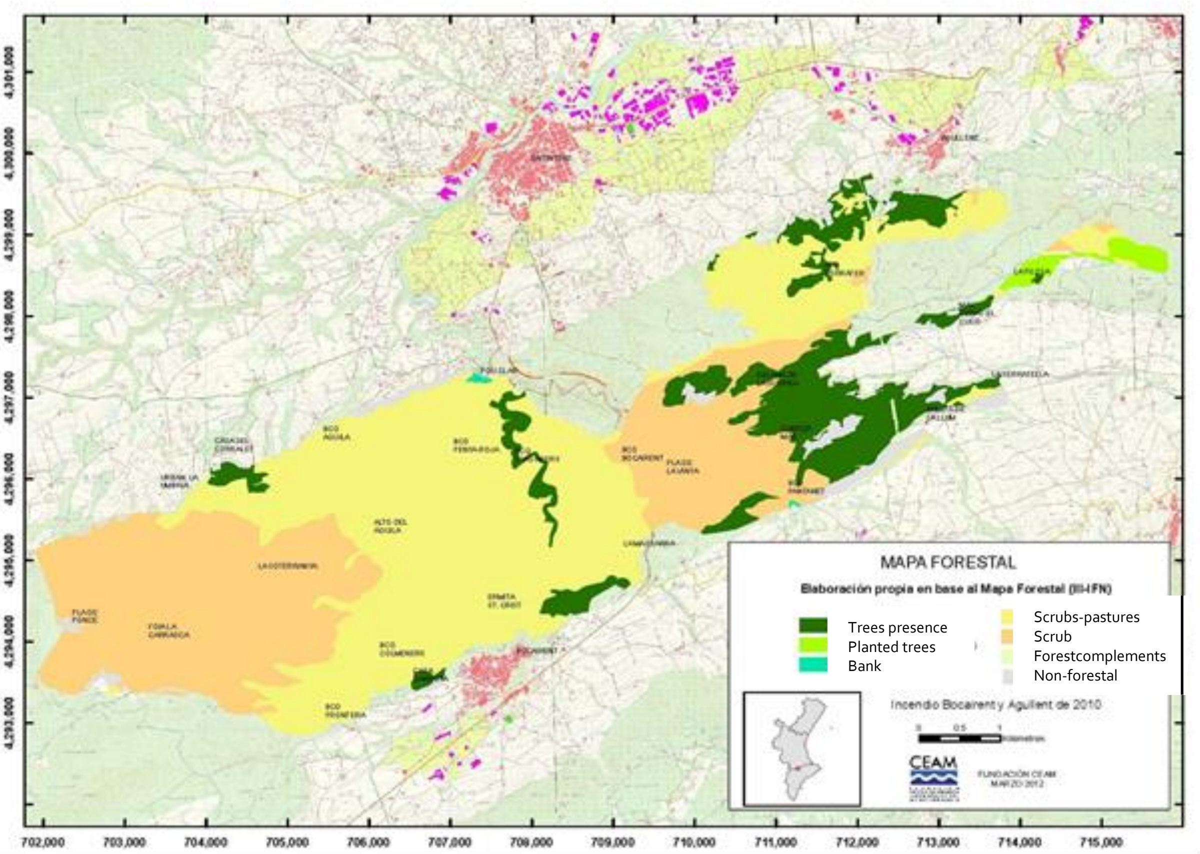

Figure 9. Distribution of vegetation. Situation before the fire of 2010. Key: Dark green: adult wooded area (presence). Light green: planted trees. Orange: scrubland. Yellow: scrubland-pastures. Dark grey: adjacent areas. Light grey: non-forested areas.

1.6. Prior identification of homogeneous environmental units

Considering the relief, lithology, vegetation and severity of the fire, homogeneous environmental units were established (Chart 4 and Figure 10):

A. *Pinus halepensis* pine forest
- Sub-unit A.1 Mature pine forest of medium-high thickness
- Sub-unit A.2 Young pine forest.

B. Scrubland
- Sub-unit B.1 Germinating scrubland.
- Sub-unit B.2 Scrubland with holm oak.

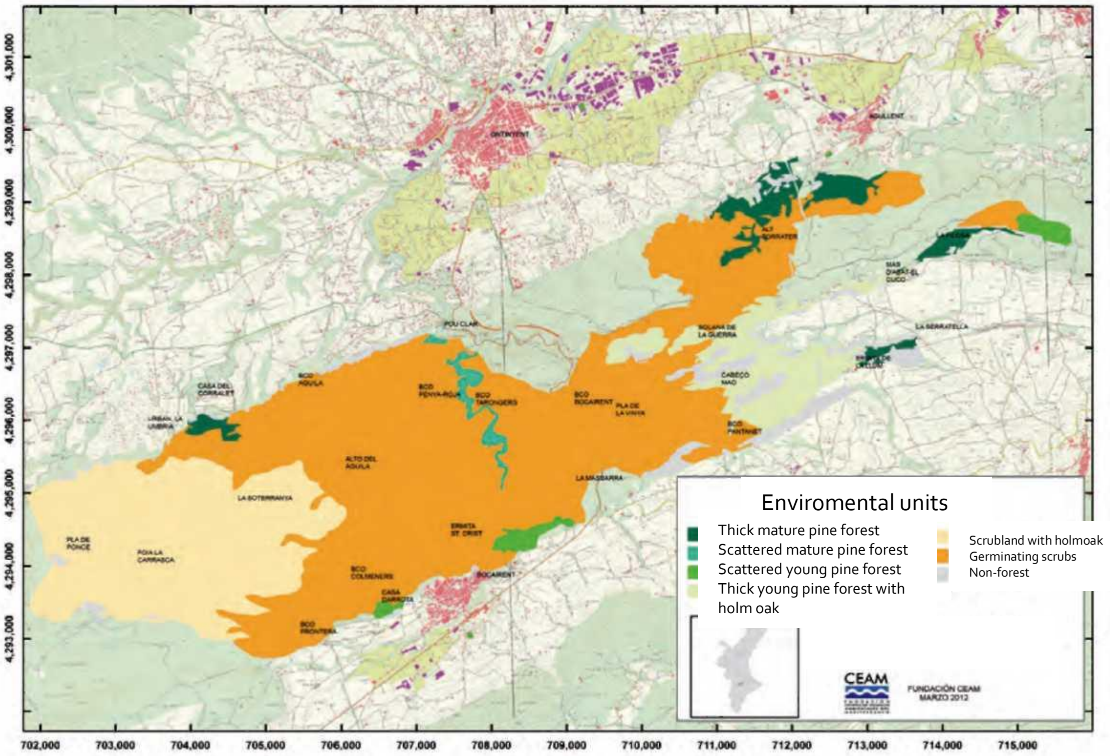

Figure 10. Identified environmental units. Key: Dark green: thick adult pine forest. Emerald green: scattered adult pine forest. Light green: scattered young pine forest. Very light green: thick young pine forest with germinating scrubland. Light orange: scrubland with holm oak. Dark range: germinating scrubland. Grey: non-forested areas.

Envronmental unit (fire area)	Sub-unit	Structure of vegetation	Specific composition	Location
SCRUBLAND (85%)	Germinating scrubland	Little growth (height below 1 m) Medium-high cover, low in wetlands	Germinating species prevail: rosemary, rockrose, gorse Resprouting species appear as isolated individuals: kermes oak, heather, cade, Mediterranean buckthor, *Rhamnus lycioides*, *Daphne gnidium*	Pía de la Vinya, upper parts of the Solana de la Guerra (Municipality of Alfafara), Alt del Turrater (Municipality of Ontinyent), upper part of the hillside of Agullent, riverbanks of Bco deis Tarongersy Bco. Bocairent.
	Scrubland with holm oak	Height: 1-1.5 m Medium-high cover	Both germinating and resprouting species prevail: kermes oak, heather, cade (*Juniperus oxycedrus*), holm oak shrubs or little tree-shaped holm oak, rosemary, rockrose, gorse	Pía de Ponce, Foia de la Carrasca (Municipality of Bocairent)
PINE FOREST (15%)	Thick mature pine forest	Pole phase-old-growth, full thick forest, natural origin (excluding la Solana de la Filosa) Scarce underbrush	*Pinus halepensis*, with isolated trees of holm oak and *Pinus pinaster* Underbrush: kermes oak, rosemary, Mediterranean buckthorn, rockrose, mastic tree, Mediterranean false brome	Surroundings of Agullent and adjacent area of the Municipality of Ontinyent, Alt del Turrater, Casa del Corralet (Municipality of Ontinyent), solana de la Filosa, Serratella (Municipality of Agres)
	Scattered mature pine forest	Pole-old-growth, Mixed with scrubland	*P. halepensis*, with isolated trees of holm oak, *P. pinaster* and *Pinus pinea*	Bco deis Tarongers, Casa de la Darrota (Municipality of Bocairent), little patches all over the burned area
	Very thick young pine forest	Shrub-sapling, regenerated after the fire of 1994, with excessive thickness Underbrush very scarce	*P. halepensis*	Lower parts of the Municipality of Alfarara, many of them terraced, in the Ermita de la MD Llum, Cabero del Maó, solana de la Guerra, solana de la Filosa. Little patches all over the burned area
	Scattered young pine forest	Shrub saplings, regenerated after the fire of 1994, mixed with scrubland	*P. halepensis*	Little patches all over the area: hillsides near Bocairent, Pía de Ponce, highest point of la Filosa, piedmont of the Municipality of Ontiyent, etc.

Chart 4. Vegetation affected by the fire of 2010 and environmental units (Summary of Gimeno et al., 2010)

2. IMMEDIATE ASSESSMENT THROUGH FIELD INSPECTION

Prior to the inspection of the area and data collection, a georeferenced mesh was established with the theoretical distribution indicated in Figure 11. Based on the accessibility, the potentially vulnerable areas and the relevance of the points of interest, routes, sampling and observation points are established. The information gathered in the field sheets was registered in the database for subsequent analysis.

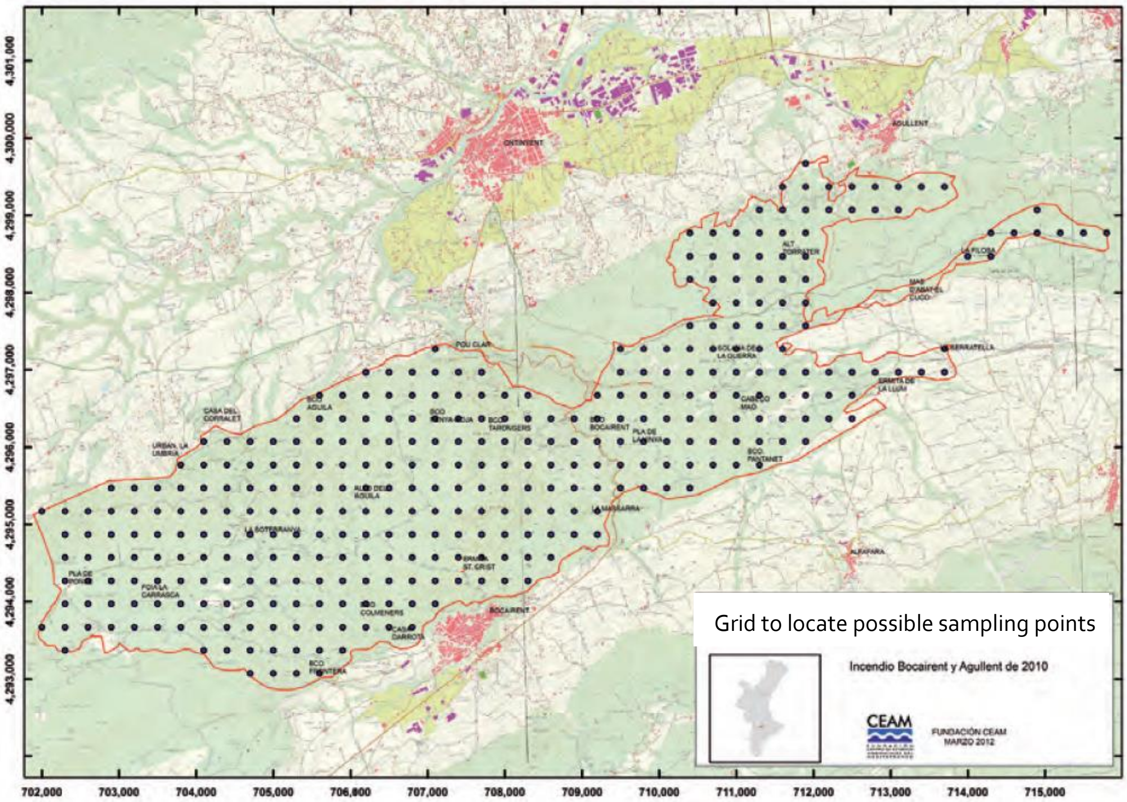

Figure 11. Theoretical distribution of the sampling points according to the predefined mesh. A total of 25 points (11 sampling points and 14 observation points) were subject to inspection.

Malla de localización de los posibles puntos de muestreo	Grid to locate possible sampling points

In the field sheets, information which, together with the data collected during the documentation phase, allows to determine the ecological impact of the fire has been gathered. This impact is obtained by incorporating the short-term ecological vulnerability of the burned area with the severity of the fire (Figure 12).

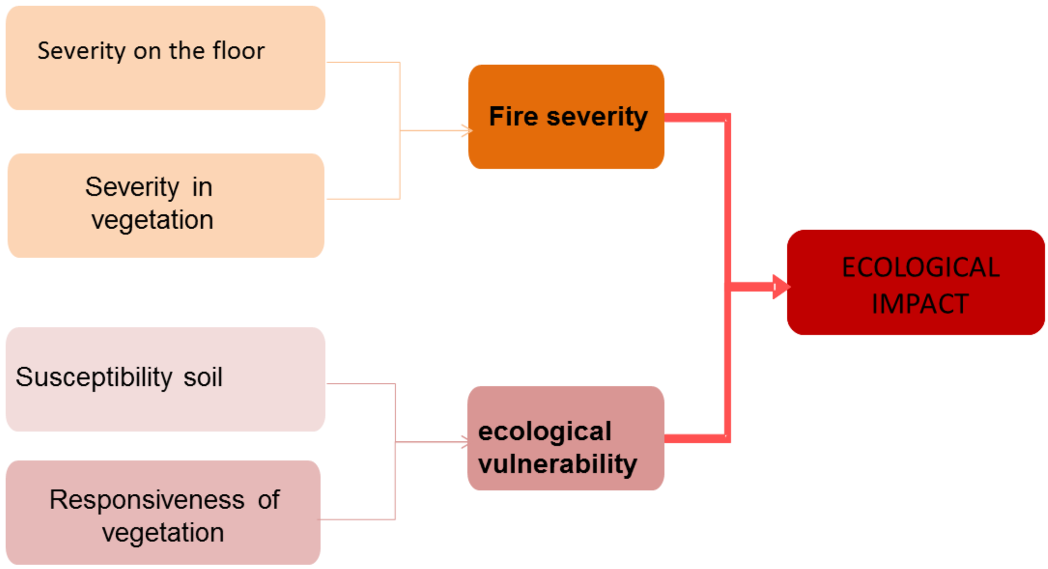

Figure 12. Diagram for fire impact assessment.

2.1. Fire severity

2.1.1. On-site assessment

The inspection of the area allows obtaining information on the severity upon vegetation and soil. Based on the vegetation units and the information of the observation points, severity on vegetation may be summarised in the terms described in Chart 5:

Chart 5. Fire severity upon vegetation.

Scrubs	Average (some twigs remain unburned) to high (diameters up to 4-5 mm are burned) depending on the biomass, the relief and the fire phase.
Mature pine forest	In general: low (more than half of the green crown remains unburned) to average (the crown is burned but dry leaves remain on it; sometimes a part of the crown, which is always less than half, preserves its green colour) High (the needles on the trees are completely burned) in Alt del Turrater and Casa del Corralet. The underbrush suffered medium-high severity.
Young pine forest	High (the needles of the trees are completely burned). The underbrush suffered medium-high severity.

2.1.2. Assessment of severity using remote sensing techniques

The field information may be completed with the information obtained by means of remote sensing. The application of severity indices obtained by means of satellite images allows to quickly obtain assessments on vast areas, to have access to information on areas which are not easily accessible, as well as to repeat the assessment to compare other areas or periods, and at an affordable cost (Key & Benson, 2006).

The severity of the fire may be estimated with the NBR or Normalized Burn Ratio index based on the combination of the mid-infrared and near-infrared bands using the following expression:

NBR = (R4 - R7) / (R4+ R7)

The R4 band reflectance is related to the leaf area and the vegetation productivity, and R7 band relates to the water content and some characteristics of the area without vegetation (Key & Benson, 2006).

The NBR index includes values between -1 and +1. Nonetheless, in order to identify the burned areas and express the magnitude of the changes in vegetation caused by the fire, the following expression is usually used:

dNBR = NBRprefire - NBRpostfire

Assuming that the burned area is relatively similar in terms of phenology and humidity in the period between the two sampling dates, the unburned areas present values close to zero. Theoretically, this last index may range between -2 and +2. According to Key and Benson (2006), it is usually between -550 and +1350 (on a scale multiplied by 1000). Chart 6 shows the severity scale used by these authors.

In the assessment of the burned area two LANDSAT-5 images have been used; these images were taken in June and November of 2010, i.e. about 3 months before and 2 months after the fire respectively. Due to the availability of images, it was not possible to compare dates closer to the fire or, failing that, in the same phenological state. This time difference may condition the results since the dates from which the comparisons have been established are very significant (Key & Benson, 2006).

Chart 6. Severity scale according to ranges of the dNBR index * 103 (taken from Key and Benson, 2006)

Level of severity	dNBR range
Resprouted after the fire	-500 / - 100
Unburned	-101 /+ 99
Low severity	+ 100 /+ 269
Medium severity	+270 /+659
High severity	+ 660 / +1300

The spatial distribution of the severity index may be observed in Figure 13. Severity is closely linked to fuel distribution, which makes sense since severity reflects the loss of organic matter (Keeley, 2009). As the fire spread evenly all over the affected area, the loss of organic matter was prompted by the fuel load existing prior to the fire.

In general, the severity values obtained by means of the dNBR index match those directly obtained in the inspection of the area. In quantitative terms, the severity of the fire may be deemed as low since 75% of the area has been affected by low severity or no severity (Figure 14). On the contrary, almost 25% presents average values (high values do not account for more than 1%). As a comparative reference, in the fire of the maritime pine forest in 2005 in Guadalajara, the percentages of severity were: high 24.28%, average 56.12% and low 19.60% (Gonzalez et al., 2009; based on AHS-INTA high spectral resolution images, of 3 metres of resolution, although the authors do not specify the relevant range).

By carrying out a detailed analysis of the spatial distribution of the index, some differences regarding the field inspections arise:

- In the Barranc dels Tarongers, the index shows severity values which are relatively higher than expected. Field research indicates that in this area, except for specific hillsides covered with pines, severity was low. This difference may be due to the relation of the index to water content and relief, or to the different phenological state of the riverside vegetation between the two images (Figure 15); these factors have an influence on the value of the NBR index.
- Almost 10% of the pixels are included in a range between 50-100 of the dNBR index. According to the scale by Key & Benson (2006), this would correspond to unburned areas, but evidence indicates that these areas have suffered the effects of the fire. On the contrary, the almost non-existent high values of severity can be noticed (less than 1%). Both observations point to the need for adjusting the intervals of the severity scale, a scale that the authors have established for a type of vegetation very different from the Mediterranean vegetation.

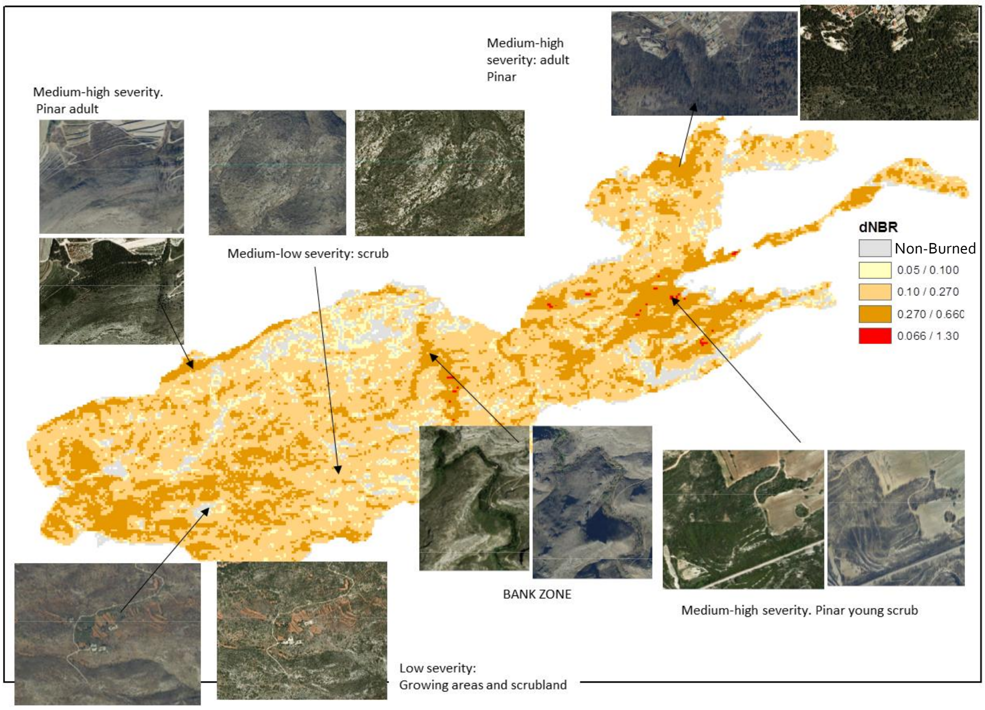

Figure 13. Distribution of the severity intervals obtained with the dNBR index. The images reflect the situation before and after the fire (based on ortophotos of 2009 and 2010). Key: Grey: unburned. Yellow: dNBR 0.05-0.10. Light orange: dNBR 0.10-0270. Dark orange: dNBR 0270-0.66. Red: dNBR 0.66-1.30.

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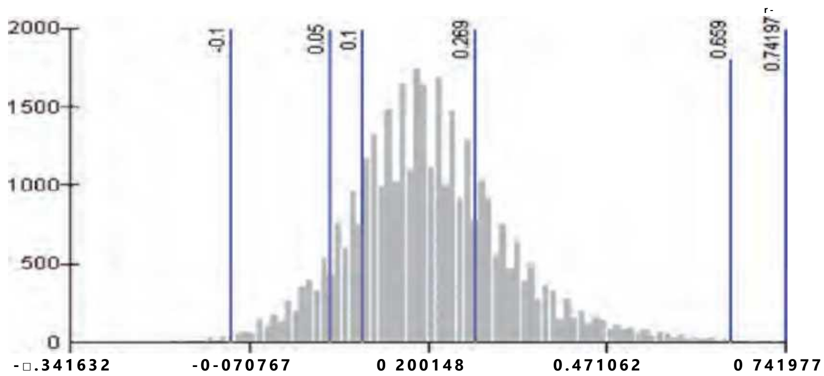

Figure 14. Histogram with the distribution of the dNBR index in the pixels included in the burned area. Most of them (75%) present values lower than the threshold 0,269, which is deemed as the limit for low severity. Almost 10% would be included in the 0.05-01 interval that, according to the scale of Key and Benson (2006), would correspond to unburned areas; however, they correspond to low severity areas. In Chart 4, the values of the index have been multiplied by 1000.

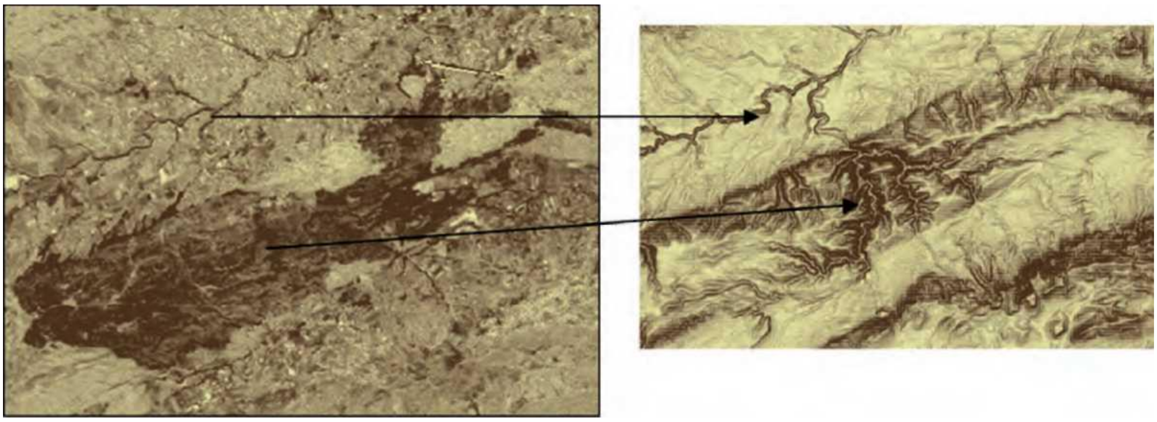

Figure 15. Left: distribution of the dNBR index over the whole image analysed (higher severity based on the colour intensity). Right: Digital elevation model. The arrows indicate the riverbed of Clariano river and the Barranc dels Tarongers. As in the Barranc dels Tarongers, the values of the dNBR index in the riverbed of Clariano river are high, which may be due to the different phenological state of the riverside vegetation, the presence of water bodies and the terrain features.

2.2. Short-term ecological vulnerability

It is worked out based on soil sensitivity and the response capacity of vegetation:

2.2.1. Soil sensitivity to water erosion

The soils developed on limestone are not very sensitive, they present multiple outcrops and high stone content, which build up in rock cracks (Figure 16).

Figure 16. ES area in burned space. Calcareous substrate consolidated with frequent rocky outcrops. At the top, flat areas and steep slopes. Only some hillsides have terraces for former crops.

Only one area which presented erosion problems before the fire was identified, and such problems were only sporadic (Chart 7). The area in question is located to the South-South-east where many hillsides were terraced for agricultural purposes, and terraces present different levels of conservation, there being some eroded embankments with rills and gullies which could be worsened by the temporary lack of vegetation. In addition, the fire was more intense in these areas.

Chart 7. Levels of risk of erosion established in the field inspections.

Geological substratum	Post-fire erosion risk
Biological and sandy limestones	Very low: the soil builds up in cracks between outcrops, high surface stone content
Dolomites and dolomitic marls	Very low due to smooth relief
Tertiary conglomerates and marls in Agullent (grown pine forest)	Low, due to terracing and to the fact that the pine forest was mildly affected. Fallen pine needles can protect the ground.
Non-consolidated substrates in Alfafara (young pine forest and shrubland)	Average: terraced hillsides (abandoned crops) with erosion phenomena before the fire.

2.2.2. Response capacity of vegetation (expected regeneration)

The main forecasts of vegetation response capacity are set out in Chart 8.

Chart 8. Regeneration forecasts of the vegetation affected by the fire (summary of report by Gimeno et al., 2010).

Vegetation	Post-fire regeneration
Germinating scrubs	The growth of scrubs with a similar structure to that of burned vegetation, although with more cistaceae species and gorse and less rosemary, can be expected. Good regeneration is expected from resprouting species, although poorly contributing to soil cover.
Scrubland with holm oaks	Good regeneration can be expected as a result of the abundance of resprouting species.

Thick mature pine forest	Good regeneration of *P. halepensis*, can be expected since the trees presented sufficient pine cones and abundant post-fire dispersal of pine nuts was observed. Brush ground vegetation regeneration is expected to be good, whether as a result of resprouting or resulting from the seed bank in the ground: rosemary, rockrose, gorse. The abundance of Mediterranean false brome prior to the fire suggests good herbaceous regeneration.
Young pine forest	Poor regeneration of *P. halepensis* can be expected, since the production of pine cones with viable seeds was quite low and the fire was severe. Scrub ground vegetation, made up by gorse, rosemary, heather, etc. ensures germination, although not with fast response. The scarcity of heath suggests low regeneration of the herbaceous stratum.

2.3. Ecological impact of fire

The integration and systematisation of the information obtained in sampling points is set out in Charts 9 and 10. Chart 9 shows, for the whole fire and for each of the assessed factors, the total percentage of points within each vulnerability and severity category. Chart 10 sets forth, for each environmental unit and the fire at large, the distribution of sampling points per impact category for vulnerability and severity.

Chart 9. Distribution of sampling points (in percentage) per environmental factor analysed and per vulnerability and severity category.

VULNERABILITY			LOW	MEDIUM	HIGH	VERY HIGH	No data
Soil sensitivity	Topography (Slope)		28	36	12	24	0
Soil sensitivity	Lithology		64	36	0	0	0
Soil sensitivity	Previous signs of erosion	Degree of erosion	96	0	4		0
Soil sensitivity	Previous signs of erosion	Terrace status	92	8	0		0
Soil sensitivity	Previous signs of erosion	Degree of crusting	100	0	0		0
Soil sensitivity	Soil protection	% Bare soil	100	0	0		0
Soil sensitivity	Soil protection	Leaf litter layer thickness	0	0	100		0
Vegetation sensitivity	Response capacity	Good germinating tree species (saplings-poles) and resprouting species	67	17		16	0
Vegetation sensitivity	Response capacity	Resprouting scrubland	0	4		56	40
Vegetation sensitivity	Response capacity	Resprouting herbaceous species	12	16		16	56
Vegetation sensitivity	Fire recurrence	Number of previous fires in the past 15 years	20	80	0	0	0
Vegetation sensitivity	Plant health status	Presence of pests and/or presence of damage by abiotic agents	100	0	0	0	0
SEVERITY			**LOW**	**MEDIUM**	**HIGH**	**VERY HIGH**	**No data**
Severity upon soil	Leaf litter affected (level)		0	63.6	36.4		0
Severity upon soil	Presence of white ash		36.4	54.5	9.1		0
Severity upon vegetation	Trees		0	33.3	16.7	41.7	8.3
Severity upon vegetation	Scrubs		0	0	72.7	27.3	0
Severity upon vegetation	Herbaceous stratum		0	36.4	63.6		0
Other specific impact signs			0	0	0	0	0

Chart 10. Summary chart (per unit and fire total) setting out the distribution of sampling points (percentage) for each vulnerability and severity category

		ECOLOGICAL IMPACT				
		LOW	MEDIUM	HIGH	VERY HIGH	No data
Unit A.1 Grown pine forest	VULNERABILITY					
	Soil sensitivity	68.6	11.4	16.6	3.4	0
	Vegetation sensitivity	30.6	21.1	0	29.1	19.2
	FIRE SEVERITY					
	Severity upon soil	18.2	59.1	22.8	0	0
	Severity upon vegetation	0	23.2	51	23	2.8
Unit A.2 Young pine forest	VULNERABILITY					
	Soil sensitivity	28.6	14.3	42.9	0	14.3
	Vegetation sensitivity	20	40	40	0	0
	FIRE SEVERITY					
	Severity upon soil	0	0	100	0	0
	Severity upon vegetation	0	0	33.3	66.6	0
Unit B. Scrubland	VULNERABILITY					
	Soil sensitivity	71.4	9.8	14.3	4.5	0
	Vegetation sensitivity	24.2	23.2	34.7	0	17.9
	FIRE SEVERITY					
	Severity upon soil	25	56.3	18.8	0	0
	Severity upon vegetation	0	31.5	49.1	15.7	3.7
Fire	VULNERABILITY					
	Soil sensitivity	68.5	11.4	16.5	3.4	
	Vegetation sensitivity	30.6	21.1	0	29.1	19.2
	FIRE SEVERITY					
	Severity upon soil	18.2	59.1	22.7	0	0
	Severity upon vegetation	0	23.2	51	23	2.8

As a whole, the data suggest low vulnerability (with mainly low or average values with regard to soil and vegetation sensitivity) and medium to high severity.

3. SELECTION OF EMERGENCY ACTIONS

The inspection of the burned area allows identifying the most vulnerable areas and to evaluate the need for emergency actions.

3.1. Control of water erosion on hillsides

In light of topography, lithology and vegetation features of most of the affected area, during the field inspection it was considered that intense erosion processes were not expected (low to medium vulnerability), at least in general, and it was determined that the area affected by the fire did not require emergency actions.

3.2. Prevention of damages caused by pests

In this area, the Pest Prevention Services had located bark beetle sources prior to the fire.

In most of the burned pine forests, crowns became partially affected, most of which kept at least a small green part on their crowns (these are the trees most prone to suffering attacks by wood-boring insects). This is why monitoring of potential bark beetle sources on burned pine forests and selective felling of trees partially affected by the fire is recommended if the risk of pest spreading were to be confirmed.

3.3. Management of burned wood according to ecological criteria

During the field visit, no significant erosion risk was detected, and it was determined that there was no need to manage burned wood as a soil conservation measure in most of the thick grown forest areas. Nonetheless, forest health or safety in urban areas justified the performance of preventive treatments of burned woods.

During this phase, the protocol to assess the treatment of burned wood was applied. The application of this protocol was conducted upon most of the trees within the affected area: the old-grown thick *P. halepensis* pine forest near the urban community of Agullent in hills V-012 and V-138, owned by the Generalitat Valenciana (approximately 30 ha).

The main environmental features of this pine forest can be summarised in:

- Substratum with biological limestones and dolomites
- Without prior symptoms of erosion
- Over 60% of the soil protected (stone content covers over 60% of the soil, leaf litter partially consumed by fire and pine trees kept some dead pine needles on their crowns, which eventually fell down)
- Hill slope length: 1200-1400 m; gradient: <15% at the bottom area, 15-35% at the top
- Scarce herbaceous and shrub resprouting, since in both cases resprouting species covered under 30% of the ground before the fire
- Severity of the fire: partially burned down leaf litter, sporadic presence of white ash (only under fuel loads)
- Existence of bark beetle sources within 2 km or less.

Extraction was conducted by means of: felling all trees (involving of the whole surface) during the winter-spring after the fire, on-site debranching, extraction of trunks through skidding, grinding woody debris with a chipper and dispersal of such.

Based on the described environmental features, the assessments set out in Chart 11 have been conducted. The criteria applied for the integration of data can be summarised in the following points:

- Soil conservation: the soil presents low vulnerability in the areas with a gradient under 15% and low/medium vulnerability in 15-35% gradients. Protection provided by the dispersal of ground wood can be positive. Therefore, a low/medium impact upon soil conservation can be expected.
- Vegetation cover regeneration. A slow regeneration can be expected (there are few resprouting species and the fire had medium severity, in some areas even with high recurrence of fires). On the other hand, grinding could have a positive impact since it would help reduce water stress.
- Spread of pests: high sensitivity as a result of the presence of bark beetle sources before the fire.
- Fuel load. Given their development and thickness, the affected forest stands provide much timber. However, the grinding process significantly reduces fuel loads.
- Reduction of habitats of small animals: medium sensitivity resulting from the relatively small area and presence of nearby pine forests.
- Reduction of nutrients and food: medium sensitivity.

Figure 17. Look of the forest in a thick adult pine forest area where timber was extracted the year after the fire.

Chart 11. Assessment of burned timber extraction activities

			ECOLOGICAL FACTORS								
				Regeneration of vegetation cover				Micro-org. source, nutrients and food		Habitat for small animals	
			Soil conservation	Establishment of vegetation, germination and settlement	Diversity and composition of species	Pest spreading	Total fuel	Food source fungi, insects and micro-org.	Source of mineral nutrients	Diversity of small forest vertebrates	Forest birds
SITE FEATURES	Substratum type	Hard materials									
		Crumbly									
		Poorly consolidated									
	Previous signs of erosion	Minor									
		Moderate									
		Severe									
	Bare soil area	<30%									
		30-60%									
		>60%									
	Gradient	<15%									
		15-35%									
		>35%									
	Resprouting species	>60%									
		30-60%									
		<30%									
	Burned tree development status	Fully thick old-growth development									
		Old-growth development (non thick). Pole phase or sapling phase, fully thick									
		Other									
	Presence of pest source within 2-4 km										
FIRE	Severity upon tree crowns	Low									
		Medium									
		High									
	Severity upon soil	Low									
		Medium									
		High									
TREATMENT	Treatment for debris	No action									
		Only tree felling									
		Trunk logging									
		Stacking									
		Chipping									
		Full skidding extraction									
FOREST STAND UNDER ASSESSMENT											
SELECTED TREATMENT											
STAND VULNERABILITY											

Impact varies according to the ecological factor taken into consideration but minor impacts prevail. This is why the application of the assessed technique can be considered acceptable in the area, although it would be preferable to adopt some additional measures to minimise the impact upon the most vulnerable ecological factors. The greatest impact occurs as a consequence of the reduction of habitats of small forest vertebrates. Impact could be minimised by leaving scattered small burned groves untreated across the affected area. These groves could take up 10% of the area and should never comprise partially affected trees, since this could prove counter-productive when controlling bark beetle pests. This minimisation technique could also have a positive impact upon the *Food sources for fungi and insects* and *Vegetation richness* factors.

■ MEDIUM-TERM ASSESSMENT

4. DIAGNOSIS OF MEDIUM-TERM EVOLUTION OF VEGETATION. MONITORING OF REGENERATION 18 MONTHS AFTER THE FIRE

18 months after the fire, in March 2012, sampling activities were conducted to analyse the evolution of the area affected by the fire. During this sampling, the assessment protocol under section IV of the Guide was applied and assessment points analysed in the September 2010 report were reviewed, alongside other relevant points, either to assess actions or to present some specific information.

4.1. Meteorology after the fire

Between the fire and the sampling, no intense cold spells or heat waves have occurred in the affected area. The distribution of rainfall has been irregular:

- During the autumn after the fire, the total volume of rainfall was 50% lower than the average in previous years (2004-2010). During the six-month period after the fire (between 09/2010 and 02/2011), approximately 180 mm were registered while the average stands at 380 mm.
- During the 2010/2011 winter, rainfall was similar to average values.
- In the spring 2011, rainfall was 20-40% over the average value.
- The summer of 2011 was 80% drier than the average, with a dry period of 125 consecutive days without any significant rainfall. Such period, between late July and late October, was only interrupted by one day with 5-10 mm rainfall.
- During the autumn of 2011, rainfall was similar to average values, although with some intense rainfall event (for example, 76 mm were registered at the nearby station of Mariola on 23/11). Maximum rainfall in the area in a period of 24 hours does not exceed the value that can be expected from a 2-year return period.

4.2. Condition of the affected area 18 months after the fire

4.2.1. Water erosion

One and a half years after the fire, no severe or widespread erosion phenomena have been detected. Only post-fire erosion symptoms were identified in some specific areas.

After the fire, forecasts suggested that the erosion risk would increase, but a year and a half later only minor laminar and rill erosion symptoms were identified in very specific areas. There are no severe or widespread phenomena.

After the fire, in the water streams that cross the burned area, no significant sediment transport or sedimentation processes have been detected. It is worth mentioning that ever since the fire no significant torrential rainfall has occurred (maximum rainfall do not exceed those predicted with a 2-year return period).

Only minor signs of sediment mobilisation have been found in some ravines to the North-East end of the affected area.

Alongside the clear erosion effects and soil degradation signs, it is worth noting the widespread existence of traffic routes resulting from the reiterated passing of motorbikes outside forest tracks. This degradation, although of a linear nature, extends across large areas of the affected space.

4.2.2. Vegetation

A.1. Adult pine forest

In general, one year and a half later, regeneration of *Pinus halepensis* is quite low.

In September 2010, an abundant dispersal of seeds originating in serotinous pine cones was observed, which suggested that the regeneration of *P. halepensis* would be good. Almost two autumns later, this forecast is only coming true at the Solana de la Filosa, an area where the soil is slightly deeper and more marly than in the other adult pine forests. The months after the fire were quite drier than the average, which could have had an impact upon germination or the subsequent development of sapling forests. On the other hand, the damage caused by rabbits to pine regeneration at the Solana de la Filosa, which can also be found in the scarce regeneration near Agullet, also suggest that fauna is playing a relevant role in *P. halepensis* regeneration issues.

Underbrush in old-grown pine forests had abundant heath (the herbaceous species *Brachypodium retusum),* and a low percentage of resprouting scrubs, mainly cade *(Juniperus oxycedrus),* kermes oak *(Quercus coccifera)* and heather *(Erica multiftora).* One and a half years after the fire, these species are those which most cover the floor, although not reaching 30% of the area. Only in scattered pine forests where prior abundance of kermes oak was high a ground coverage of 30-60% is achieved. Amongst the most frequent germinating scrubs, it is worth noting *Cistus albidus* and *Cistus monspeliensis.* In sporadic terraced areas, high regeneration levels of gorse are found.

A.2. Young pine forest

The regeneration of *P. halepensis* was non-existent or very low, clearly insufficient to recover the burned forests as was predicted in the report drafted in September 2010.

B. Scrubland

One and a half years after the fire, the most widespread vegetation cover is provided by the resprouting species *B. retusum,* even though in most cases it does not reach 30%. Only in thalwegs and piedmont with slightly deeper and more humid soils it can cover larger areas.

Figure 18. Young pine forest regenerated from the 1994 fire, very thick, which suffered a severe fire (South-East area of the fire).

Resprouting scrubs are not abundant and provide covers much lower than 30%, where the dominating species are *J. oxycedrus, Q. coccifera, E. multiflora, D. gnidium* and to a lesser extent *Rhamnus alaternus* and *R. lycioides*. Their current scarcity is due to the fact that they were equally scarce before the fire. In some specific areas, the coverage of germinating scrubs is equal or higher than that of resprouters. The most abundant germinating scrubs are Cistaceae, whilst rosemary and gorse appear in fewer cases.

In September 2010, it was predicted that scrubs in the burned area would recover with a similar structure than the previous one. A very significant and rapid response by Cistaceae has been identified, as predicted, while that of gorse is not as high as expected. Resprouting species show good regeneration levels but were scarce before the fire, so in most areas they cannot contribute much to the post-fire ground cover. Only in thalwegs, piedmont and to the West end of the area there are significant areas covered by resprouters.

Even though the regeneration of *U. parviftorus* in the burned area is scarce, some specific areas where high germination levels have occurred have been identified. In all cases, these are small surfaces: thalwegs, abandoned agricultural terraces and hillsides on soft calcareous substratum where there used to be scrubland dominated by germinating species and non-thick pine forests before the fire.

<u>Flora and habitats worthy of mention</u>

Gallery formations at Barranc dels Tarongers, both tree and scrub formations, have been only slightly affected by the fire, so many green patches remain in place, particularly where the ravine is steep and humid. The ravine presents steep hillsides and widespread outcrops. As a result, the fire left many unburned vegetation groves where there were many outcrops and kermes oak. As a consequence, the impact of the fire upon rock vegetation and indigenous flora has not been particularly severe within the SCI area.

Figure 19. Germinating scrubs and small groups of adult pines. 18 months after the fire, vegetation covers 30-60% of the floor mainly due to the presence of kermes oak, Mediterranean false brome and Cistaceae.

4.3. Assessment of actions

4.3.1. Burned timber management

Prevention of erosion risks

In the areas where burned timer was managed, there were no high erosion risks so there was no need to conduct a burned timber treatment as a soil conservation measure. There were no rills, gullies or run-off concentration points either which would suggest the need to build up fascines. As a result, grinding seems to be the most reasonable option although in hills V-012 and V-138, near the urban area of Agullent, there is still some thick and fine non-chipped debris pending spreading.

It is recommended to remove forest debris from extraction routes, grind them and scatter them over said routes and nearby soil. Also, when these works are completed, it would be recommendable to repair the sporadic damage that may have been caused to the paths that run through the area.

Pest prevention

In the area of the fire there are two risk factors for the spreading of pests (presence of pest sources and weakened trees). After the fire, bark beetle attacks upon pines affected by average-severity fire (partially burned crown), both in areas where burned timber was left unmanaged and in other areas where timber extraction was conducted although some tree areas partially affected by fire were left standing.

To the West of the affected area, the death of pines further to the fire has been registered. Monitoring of potential bark beetle sources in these areas would be recommendable, particularly at the Barranc dels Tarongers where there is a relatively large adult pine forest which was affected with different severity levels. If bark beetle sources were to be found, they should be eliminated and selective felling of partially affected trees should be conducted.

Risk prevention

For safety reasons, burned trees near busy areas, such as mountain chapels, recreational areas and some forest tracks and paths have been cut down. These felling activities should also reach the areas near urban communities, mainly near towns and cities. These actions should follow the technical standards included in Forest Fire Prevention Plans

Other remarks

To contribute to forest bird fauna development, some trees could be left standing as tree perches. In any case, trees to be left standing (10%) must be dead, since partially affected trees present high plant health risks, and must be away from tracks or paths so as to prevent any impact upon passers-by. Trees to be left standing should be large-sized and stable. It seems recommendable to leave these groves preferably in the topmost and middle-slope areas, since the lowest areas border on living forest areas not affected by the fire.

As per the actions conducted upon water streams, they could also be used to reduce the abundance of invasive species such as the giant cane or *Ailanthus altíssima.*

4.3.2. Planting

The range of actions conducted are not very extensive and obtained very unalike results. Techniques (manual dibbling) and species used (mainly holm oaks and, to a lesser extent, pines) have not caused any negative impact although they will have low landscape impact too.

Both as a result of the intense activity of stakeholders and their involvement, it would be advisable that the forest management keeps public participation methods to agree and coordinate actions that could be undertaken in the near future.

Figure 20. Small forest planting conducted manually by individuals at the Municipality of Agullent.

4.4. Expected evolution in the medium term (10-20 years)

4.4.1. Erosion

The period of greatest water erosion risk takes place during the first year after the fire. When vegetation covers 30-40% of the floor, it starts to show some positive impact with regard to erosion control. Once it covers 60%, erosion protection becomes fully efficient (Beyers, 2009).

One and a half years after the fire, only isolated areas have reached vegetation covers of over 60%: thalwegs, piedmont or terraces covered by pine forests with open canopies or scrubland with large amounts of resprouting species. In these areas, in addition to a good recovery of resprouting scrubs, a good and rapid recovery of the herbaceous species *B. retusum* has taken place. Considering all strata, the vegetation cover stands between 30-60% but there are areas covered by germinating scrubs whose cover is even under 30%. However, in light of the amounts of stone content and burned wood debris, the percentage of bare soil is under 30% in most of the burned area. In specific areas with terraces covered by young pines, the percentage of bare soil is 30-60%.

At present, the vegetation cover (although still scarce) alongside the surface stone content and the debris of burned wood play a relevant role in soil protection, which means that laminar erosion has dropped remarkably. On the other hand, 18 months after the fire there are not widespread erosion processes.

4.4.2. Vegetation

Scrublands are expected to see the recovery of a community with a similar structure than that existing before the fire. In the areas dominated by germinating species, the presence of cistaceae is expected to increase and the abundance of rosemary to drop.

In most old-grown pine forests where all trees were damaged by the fire, no regeneration or very slight regeneration has been found. This is why we could expect for these forests to disappear or become small groves or isolated trees. The only exception could be the burned forest area in Solana de la Filosa, provided that the regeneration can survive the damages caused by wild fauna. In this case, there is also an old-grown pine forest around the burned area that provides abundant seeds on an on-going basis.

The pine forests in Barranc dels Tarongers are mostly non-thick and a significant part of the trees have been hardly affected by the fire. The dispersal of pine nuts from living trees is expected to allow the recovery of part of the burned pine forest provided that there are not any fires in the near future.

Finally, it has been confirmed that the absence of post-fire regeneration will involve the loss of pine forests.

As a result, a loss of forest and resilience to new fires can be expected in the medium term, enhancing the trend registered in this area since the 1970s.

4.4.3. Combustibility

There were patches of young thick pine forests in the area that fell under fuel model no. 4. After the fire, large amounts of dead, unburned vegetation remained in these areas (pine trunks and branches), which in most cases have been extracted. A part of these trunks have naturally fallen down and this trend is expected to continue. In these areas, the risk of future fires is expected to be high in the short term, as loads are similar to fuel model no. 10. Thick regeneration of *P. halepensis* that would entail high medium-term risks is not foreseen for any area.

The regeneration of *U. parviftorus* does not suggest that thick scrubland will grow in large areas. In any case, these highly combustible scrubs may appear in small areas. In the medium term, they could give rise to fuel model no. 6.

In general, scrubs in the burned area before the fire presented an incomplete cover pattern and low development statuses before the fire, falling under fuel models no. 5 and 2. No formations with high risks of fire can be expected in the medium term.

To the Westernmost end of the area, kermes oak and holm oak were the most abundant and the level of vegetation development was slightly higher (fuel model no. 6). Nonetheless, scrub patches that presented horizontal continuity were not very large, since they were distributed in a mosaic pattern with other open scrubland (fuel model no. 2). In the medium term, similar scrubs to that existing before the fire are expected to grow, although extensive scrubland formations with high levels of fuel and continuous patterns are not.

In addition to the above recommendations, we could also advise to either remove or grind dead trunks in very thick young pine forests in low areas. This way, large fuel amounts in the future would be avoided and therefore fire risks would be reduced. Irrespective of the ownership status of the land, it is recommended that burned timber management works follow homogeneous technical criteria, avoiding practices that could have a negative impact on the ecosystem such as burning debris.

As a result of the high frequency of fires in the area, actions focusing on reducing fire recurrence both in the short and medium terms must be prioritised. To the extent that these measures are proven efficient, active restoration actions could be proposed:

Recovery of pine forests in areas where there used to be thick pine forests before the fire but that have not properly regenerated after the fire. Priority should be focused on the areas where there is a lower fire recurrence, planting pines and holm oaks simultaneously.

An increase in the resilience of germinating scrubs by means of planting/seeding of resprouting scrub and tree species. For the purpose of cutting down the progressive degradation of scrubs and so as to increment forest resilience. Adding some species that bear fleshy fruits could be interesting to contribute to vertebrate fauna development.

There are no direct forest exploitations in the area affected, excepting small wild game. However, public use is frequent (particularly in Ontinyent, Agullent and Bocairent): recreational areas, hiking, ATB, motocross, etc. In addition, many local stakeholders are actively involved in forest conservation and restoration. In order to foster and benefit from this potential, establishing meeting points and increasing the coordination of all actions would be recommendable so that actions aimed to achieve common goals can be conducted under the same technical management and to a relevant extent. These actions, as mentioned above, should be initially oriented to prevent new fires.

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ADDENDUM II

ASSIGNMENT OF DOMINANT REPRODUCTIVE STRATEGIES IN VEGETATION SPECIES AND FORMATIONS IN THE 1:25,000 FORESTRY MAP

■ ADDENDUM II

ASSIGNMENT OF DOMINANT REPRODUCTIVE STRATEGIES IN SPECIES AND FORMATIONS IN THE 1:25,000 FORESTRY MAP.

List of species identified in the Forestry Map. Some widely distributed species (such as *Dhagne ignidium*) have been added to the species included in the data model[13]. The assignment of forest strategies has been conducted based on the information gathered from several sources: Pausas & Paula (2005), Paula & Pausas (2009) and other databases.

List of species with resprouting strategy			
Adenocarpus decorticans	*Lycium intricatum*	*Retama monosperma*	*Teucrium pumilum*
Adenocarpus gibbsianus	*Lygeum spartum*	*Retama sphaerocarpa*	*Thapsia villosa*
Arbutus canariensis	*Malus sylvestris*	*Rhamnus alaternus*	*Thuja*
Arbutus unedo	*Marrubium vulgare*	*Rhamnus alpinus*	*Thymelaea calycina*
Crataegus lacinata	*Medicago arborea*	*Rhamnus frangula*	*Thymelaea dioica*
Crataegus laevigata	*Medicago suffruticosa*	*Rhamnus glandulosa*	*Thymelaea hirsuta*
Daphne laureola	*Melica ciliata*	*Rhamnus lycioides*	*Thymelaea tartonraira*
Dhagne ignidium	*Melica uniflora*	*Rhamnus myrtifolius*	*Thymelaea tinctoria*
Crataegus monogina	*Mesembryanthemum nodiflorum*	*Rhamnus oleoides*	*Thymelaea villosa*
Chamaecytisus proliferus	*Molinia caerulea*	*Rhamnus saxatilis*	*Thymus bracteatus*
Euphorbia characias	*Morus alba*	*Rhododendron ferrugineum*	*Thymus longiflorus*
Euphorbia flavicoma	*Morus nigra*	*Rhus coriaria*	*Thymus membranaceus*
Euphorbia serrata	*Muscari comosum*	*Robinia pseudoacacia*	*Thymus piperella*
Fagus sylvatica	*Muscari neglectum*	*Rosa canina*	*Thymus praecox*
Festuca arundinacea	*Myrica faya*	*Rosa micrantha Borrer*	*Thymus pulegioides*
Festuca elegans	*Myrtus communis*	*Rosa pouzinii*	*Thymus vulgaris*
Festuca indigesta	*Narcissus requienii*	*Rosa sempervirens*	*Tilia cordata*
Festuca lemanii	*Nardus stricta*	*Rubia peregrina*	*Tilia platyphyllos*
Festuca nevadensis	*Nerium oleander*	*Rubus caesius*	*Trifolium pratense*
Festuca paniculata	*Nicotiana glauca*	*Rubus canescens*	*Tuberaria globulariifolia*
Festuca rubra	*Ocotea phoetens*	*Rubus idaeus*	*Typha angustifolia*
Ficus carica	*Olea europaea*	*Rubus ulmifolius*	*Typha latifolia*
Foeniculum vulgare	*Ononis fruticosa*	*Rubus ulmifolius*	*Ulex baeticus*
Fraxinus angustifolia	*Ononis minutissima*	*Rumex acetosella*	*Ulex borgiae.*
Fraxinus excelsior	*Ononis natrix*	*Ruscus aculeatus*	*Ulex europaeus*
Fraxinus ornus	*Ononis pusilla*	*Ruscus hypophyllum*	*Ulex gallii*
Galium album Miller ssp.	*Ononis spinosa*	*Salicornia ramosissima*	*Ulex minor*
Galium corrudifolium	*Ononis tridentata*	*Salix alba*	*Ulmus glabra*
Galium fruticescens	*Ophrys scolopax*	*Salix atrocinerea*	*Ulmus minor*
Galium lucidum	*Ophrys sphegodes*	*Salix babylonica*	*Ulmus pumila*
Galium pinetorum	*Opuntia sp.*	*Salix canariensis*	*Urginea maritima*
Galium verum	*Orchis morio*	*Salix cantabrica*	*Vaccinium myrtillus*
Genista berberidea	*Osyris alba*	*Salix caprea*	*Viburnum lantana*
Genista florida	*Osyris quadripartita*	*Salix eleagnos*	*Viburnum rigidum*
Genista hirsuta	*Oxalis acetosella*	*Salix fragilis*	*Viburnum tinus*
Genista hispanica	*Pancratium maritimum*	*Salix purpurea*	*Vincetoxicum nigrum*
Genista pumila	*Paronychia argentea*	*Salix spp.*	*Viola alba Besser*
Genista umbellata	*Paronychia suffruticosa Lam.*	*Salix viminalis*	*Viola odorata*
Genista valentina	*Periploca laevigata*	*Salsola genistoides*	*Viola reichenbachiana*
Gladiolus illyricus	*Persea indica*	*Salvia lavandulifolia*	*Vitis vinifera*
Gladiolus italicus	*Phillyrea angustifolia*	*Salvia pratensis*	*Withania frutescens*
Gleditsia triacanthos	*Phillyrea latifolia*	*Salvia verbenaca*	*Zizyphus lotus*
Globularia alypum	*Phillyrea media*	*Sambucus nigra*	
Globularia vulgaris	*Phlomis crinita*	*Sambucus palmensis*	
Gypsophila hispanica	*Phlomis lychnitis*	*Sambucus racemosa*	
Gypsophila struthium	*Phlomis purpurea*	*Sanguisorba minor Scop.*	

[13] Fichero MFE25_Publicacion_dd_tcm7-192639.xls en : http://www.magrama.gob.es/es/biodiversidad/temas/ecosistemas-y-conectividad/mapa-forestal-de-espana/metodologia_mfe_25.aspx

Genista scorpius	*Phoenix dactylifera*	*Santolina chamaecyparissus*	
Genista spartioides	*Phragmites australis*	*Santolina rosmarinifolia*	
Genista triacanthos	*Pinus canariensis*	*Scabiosa triandra*	
Genista tridens	*Pistacia atlantica*	*Scabiosa turolensis*	
Halimium alyssoides	*Pistacia lentiscus*	*Schoenus nigricans*	
Halimium lasianthum	*Pistacia terebinthus*	*Scilla autumnalis*	
Hedera helix	*Plantago albicans*	*Scilla monophyllos Link*	
Hedysarum boveanum	*Platanus hispanica*	*Scirpus maritimus*	
Helichrysum stoechas	*Platanus orientalis*	*Scorzonera graminifolia*	
Helictotrichon filifolium	*Poa angustifolia*	*Securinega tinctoria*	
Helleborus foetidus	*Polygala calcarea*	*Sedum sediforme*	
Hieracium castellanum.	*Polygala microphylla*	*Seseli elatum*	
Hieracium pilosella	*Polygala rupestris*	*Sideritis hirsuta*	
Hippocrepis comosa	*Polygala vulgaris*	*Silene legionensis*	
Hippocrepis scorpioides	*Polypogon viridis*	*Silene mellifera*	
Holcus lanatus	*Populus alba*	*Simethis planifolia*	
Holoschoenus vulgaris	*Populus canadensis*	*Smilax aspera*	
Hyparrhenia hirta	*Populus canescens*	*Sophora japonica*	
Hypericum perforatum	*Populus nigra*	*Sorbus aria*	
Hypochoeris radicata	*Populus tremula*	*Sorbus aucuparia*	
Ilex aquifolium	*Populus x canadensis*	*Sorbus chamaemespilus*	
Ilex canariensis	*Populus x euramericana*	*Sorbus domestica*	
Ilex platyphylla	*Potentilla neumanniana*	*Sorbus latifolia*	
Inula montana	*Prunella laciniata*	*Sorbus torminalis*	
Iris pseudacorus	*Prunus avium*	*Spartina densiflora*	
Jasminum fruticans	*Prunus dulcis*	*Spartina stricta*	
Jasonia tuberosa	*Prunus lusitanica*	*Spartium junceum*	
Juglans nigra	*Prunus mahaleb*	*Stachys officinalis*	
Juglans regia	*Prunus padus*	*Stauracanthus boivinii*	
Juncus conglomeratus	*Prunus ramburii*	*Stauracanthus genistoides*	
Juniperus oxycedrus	*Prunus spinosa*	*Staurucanthus boivinii*	
Knautia arvensis	*Pseudarrhenatherum longifolium*	*Stellaria holostea*	
Koeleria crassipes	*Pteridium aquilinum*	*Stipa gigantea*	
Koeleria vallesiana	*Pterospartum tridentatum*	*Stipa offneri*	
Laurus nobilis	*Pyrus bourgaeana*	*Stipa parviflora Desf.*	
Laurus novocanariensis	*Pyrus spp.*	*Stipa pennata*	
Ligustrum vulgare	*Quercus canariensis*	*Stipa tenacissima*	
Limodorum abortivum	*Quercus cerrioides*	*Suaeda maritima*	
Limoniastrum monopetalum	*Quercus coccifera*	*Suaeda vera*	
Linum narbonense	*Quercus faginea*	*Tamarix afriacana*	
Lithodora diffusa	*Quercus fruticosa*	*Tamarix africana*	
Lithodora fruticosa	*Quercus humilis*	*Tamarix boveana*	
Lithodora prostrata	*Quercus ilex*	*Tamarix canariensis*	
Lonicera etrusca	*Quercus lusitanica*	*Tamarix gallica*	
Lonicera implexa	*Quercus petraea*	*Teline linifolia*	
Lonicera periclymenum	*Quercus pyrenaica*	*Tetraclinis articulata*	
Lonicera pyrenaica	*Quercus robur*	*Teucrium capitatum*	
Lonicera xylosteum	*Quercus rubra*	*Teucrium chamaedrys*	
Lotus corniculatus	*Quercus suber*	*Teucrium fruticans*	
Linum suffruticosum	*Rahmnus lycioides*	*Teucrium gnaphalodes*	
Luzula lactea	*Ranunculus bulbosus*	*Teucrium polium*	
Luzula lutea	*Reichardia picroides*	*Teucrium pseudo-chamaepitys*	

List of species with germinating strategy		
Abies alba	*Euphorbia nicaeensis*	*Ornithopus perpusillus*
Abies pinsapo	*Euphorbia peplus*	*Pallenis spinosa*
Agrostis capillaris	*Festuca hystrix*	*Papaver rhoeas*
Aira caryophyllea	*Filago pyramidata*	*Paronychia capitata*
Althaea hirsuta	*Filago vulgaris Lam.*	*Petrorhagia prolifera*
Alyssum alyssoides	*Filipendula vulgaris*	*Phagnalon rupestre*
Anagallis arvensis	*Fumana ericoides*	*Phagnalon saxatile*
Andryala integrifolia	*Fumana hispidula*	*Picea abies*
Anthemis arvensis	*Fumana laevipes*	*Picris comosa*
Anthyllis tetraphylla	*Fumana procumbens*	*Picris hieracioides*
Anthyllis vulneraria	*Fumana thymifolia*	*Pinus brutia*
Antirrhinum barrelieri	*Galactites tomentosa*	*Pinus halepensis*
Aphanes arvensis	*Galium aparine*	*Pinus nigra*

Aphanes microcarpa	*Galium divaricatum*	*Pinus pinaster*
Arabidopsis thaliana	*Galium pumilum*	*Pinus pinea*
Arabis hirsuta	*Galium setaceum*	*Pinus radiata*
Arenaria serpyllifolia	*Gastridium ventricosum*	*Pinus strobus*
Armeria pungens	*Genista cinerea*	*Pinus sylvestris*
Arnoseris minima	*Genista polyanthos*	*Pinus uncinata*
Artemisia barrelieri	*Geranium columbinum*	*Piptatherum miliaceum*
Asperula aristata fil.	*Geranium purpureum*	*Plantago afra*
Asplenium onopteris	*Geranium robertianum*	*Plantago crassifolia*
Asterolinon linum-stellatum	*Gymnocarpium*	*Plantago ovata*
Astragalus incanus	*Halimione portulacoides*	*Potentilla cinerea*
Atractylis cancellata	*Halimium atripicifolium*	*Potentilla erecta*
Biscutella laevigata	*Halimium atriplicifolium*	*Prunella grandiflora*
Bombycilaena erecta	*Halimium commutatum*	*Pseudotsuga menziesii*
Brassica tournefortii	*Halimium halimifolium*	*Rapistrum rugosum*
Briza maxima	*Halimium halmifolium*	*Reichardia tingitana*
Briza media	*Halimium ocymoides*	*Reseda phyteuma*
Bromus erectus	*Halimium viscosum*	*Reseda suffruticosa*
Bromus hordeaceus	*Halimium umbellatum*	*Rosmarinus officinalis*
Bromus madritensis	*Helianthemum almeriense*	*Ruta angustifolia Pers.*
Bromus rubens	*Helianthemum apenninum*	*Salsola kali*
Bupleurum baldense	*Helianthemum cinereum*	*Salsola vermiculata*
Bupleurum praealtum	*Helianthemum hirtum*	*Sambucus ebulus*
Bupleurum spinosum	*Helianthemum lavandulifolium*	*Sanicula europaea*
Cakile maritima	*Helianthemum squamatum*	*Satureja cuneifolia*
Calendula arvensis	*Helianthemum syriacum.*	*Satureja montana*
Cardamine hirsuta	*Helianthemum marifolium*	*Satureja obovata*
Carduus pycnocephalus	*Helichrysum italicum*	*Satureja salzmannii*
Carrichtera annua	*Heliotropium europaeum*	*Saxifraga oppositifolia*
Cedrus atlantica	*Herniaria fruticosa*	*Scirpus holoschoenus*
Cedrus deodara	*Herniaria glabra*	*Scorpiurus muricatus*
Cedrus libani	*Hippocrepis bourgaei*	*Senecio gallicus*
Centaurea antennata	*Hippocrepis ciliata*	*Senecio jacobaea*
Centaurea boissieri	*Hippocrepis scabra.*	*Senecio vulgaris*
Centaurea hyssopifolia	*Hornungia petraea*	*Sherardia arvensis*
Centaurium erythraea	*Hypericum humifusum*	*Sideritis angustifolia*
Centranthus calcitrapae	*Iberis crenata*	*Sideritis incana*
Centranthus ruber	*Inula conyza DC.*	*Sideritis mugronensis*
Cephalaria leucantha	*Jasione montana*	*Silene italica*
Cerastium glomeratum	*Juncus bufonius*	*Silene latifolia Poiret ssp. alba*
Cerastium pumilum	*Juniperus cedrus*	*Silene nutans*
Chaenorhinum minus	*Juniperus communis*	*Silene sclerocarpa*
Chamaecyparis lawsoniana	*Juniperus phoenicea*	*Silene secundiflora*
Chondrilla juncea	*Juniperus sabina*	*Silybum marianum*
Cirsium arvense	*Juniperus thurifera*	*Sixalix atropurpurea*
Cirsium vulgare	*Lactuca serriola*	*Sonchus asper*
Cistus albidus	*Lactuca viminea*	*Sonchus oleraceus*
Cistus clusii	*Lamarckia aurea*	*Staehelina dubia*
Cistus crispus	*Lamium amplexicaule*	*Stipa capillata*
Cistus ladanifer	*Larix decidua*	*Taraxacum officinale*
Cistus laurifolius	*Larix leptolepis*	*Taxus baccata*
Cistus libanotis	*Larix x eurolepis*	*Teesdalia nudicaulis*
Cistus monspeliensis	*Lavandula angustifolia*	*Telephium imperati*
Cistus populifolius	*Lavandula dentata*	*Teucrium expansum*
Cistus psilosepalus	*Lavandula stoechas*	*Thymus baeticus*
Convolvulus siculus	*Lavandula latifolia*	*Thymus hyemalis*
Conyza canadensis	*Leontodon taraxacoides*	*Thymus leptophyllus*
Coronilla scorpioides	*Lepidium subulatum*	*Thymus mastichina*
Cortaderia selloana	*Leucanthemopsis pallida*	*Origanum vulgare*
Crepis pulchra	*Leucanthemum vulgare*	*Thymus zygis*
Crepis sancta	*Limonium dichotomum*	*Torilis nodosa*
Crepis vesicaria	*Linaria simplex*	*Tragopogon porrifolius*
Crucianella angustifolia	*Linaria spartea*	*Trifolium angustifolium*
Cupressus arizonica	*Linum strictum*	*Trifolium arvense*
Cupressus glabra	*Logfia minima (Sm.)*	*Trifolium campestre*
Cupressus macrocarpa	*Lolium perenne*	*Trifolium glomeratum*
Cupressus sempervivens	*Lophochloa cristata*	*Trifolium stellatum*
Cynosurus echinatus	*Lotus creticus*	*Tuberaria guttata*
Desmazeria rigida	*Malva sylvestris*	*Tuberaria lignosa*
Dianthus hispanicus	*Medicago lupulina*	*Ulex parviflorus*
Diplotaxis erucoides	*Medicago marina*	*Urospermum picroides*

Diplotaxis harra	*Medicago minima*	*Verbascum rotundifolium*
Drosophyllum lusitanicum	*Medicago polymorpha*	*Veronica arvensis*
Echinospartum horridum	*Melica minuta*	*Veronica polita*
Echium vulgare	*Mercurialis annua*	*Veronica triphyllos*
Erica cinerea	*Micropyrum tenellum*	*Vicia cracca*
Erica umbellata	*Minuartia hybrida*	*Vicia parviflora*
Erodium cicutarium	*Misopates orontium*	*Vulpia myuros*
Erophila verna l	*Onobrychis supina*	*Vulpia unilateralis*
Erucastrum virgatum	*Ononis aragonensis*	
Euphorbia exigua	*Ononis ornithopodioides*	
	Ornithopus compressus	

List of unassigned species		
Anagyris foetida	*Genista baetica*	*Rhododendron ponticum*
Artemisia canariensis	*Genista balansae*	*Ribes alpinum*
Artemisia reptans	*Genista linifolia*	*Ribes rubrum*
Berberis vulgaris	*Genista monspessulana*	*Rosmarinus tomentosus*
Buplerum gibraltaricum	*Genista patens*	*Rumex lunaria*
Cistus symphytifolius	*Genista tridentata*	*Sarothamnus scoparius*
Coronilla emerus	*Genista triflora*	*Sarothamnus vulgaris*
Cupressus lusitanica	*Genista versicolor*	*Sideroxylon marmulano*
Cytisus baeticus	*Heberdenia bahamensis*	*Thymus albicans*
Cytisus malacitanus	*Hypericum canariensis*	*Thymus granatensis*
Cytisus tribracteolatus	*Kleinia neriifolia*	*Ulex canescens*
Daphne mezereum	*Launaea arborescens*	*Ulex eriocladus*
Dracaena drago	*Lavandula lanata*	*Vella spinosa*
Echinospartum boissieri	*Maytenus canariensis*	*Visnea mocanera*
Erica erigena	*Maytenus senegalensis*	
Euonymus europaeus	*Paliurus spina-christi*	
Euphorbia aphylla	*Phoenix canariensis*	
Euphorbia canariensis	*Picconia excelsa*	
Euphorbia handiensis	*Pleiomeris canariensis*	

Scrub formations with dominant germinating strategy
Gorse, furze and similar scrub communities (Mediterranean climate)
Spanish lavender scrub communities (Lavandula stoechas, L. pedunculata, L. viridis)
Erinaceae and puncture vine scrub communities (mid- and high-altitude)
Halimium species scrub communities (Halimium spp. pl.)
Mixed Cistus species scrub communities (Cistus spp. pl.)
Cistaceae species scrub communities
Haloxerophytic scrub communities (salty soils: arid zones)
Mixture of Lamiaceae and Thymus scrub communities (including woody steppes, woody grasslands and similar communities)
Rosemary scrub communities
Juniperus scrub communities (Juniperus sabina)
Juniperus sabina and juniper scrub communities

Scrub formations with dominant resprouting strategy
Blueberry scrub communities (Vaccinium myrtillus and others)
Phillyrea angustifolia scrub communities
Phillyrea latifolia scrub communities
Atlantic or sub-Atlantic gorse (furze) scrub communities (Ulex spp.) Atlantic climate
Artemisia scrub communities (Artemisia spp.)
Santolina spp. and Helichrysum sp. scrub communities
(Sub)Hydrophilic heathlands (Erica cackiana, E. tetralix, E. ciliaris) and hydrophilic and subxerophilic mixed heathlands
Mesophilic to xerophilic heathlands and pure or mixed ling scrub communities (including mixed Ericaceae scrubs)
Orophilic heathlands and low Ericaceae scrub communities in high altitudes (Loiseleuria, Arct.alpina, Pyrola, Empetrum nigrum)
Heathlands, Ericaceae scrubs and similar groupings
Buxus sempervirens and B. balearica scrub communities

Pterospartum tridentatum scrub communities
Adenocarpus complicatus and Adenocarpus hispanicus scrub communities
Pistacia terebinthus scrub communities
Quercus coccifera scrub communities
Glycohydrophilic or phreatophilic scrub and sub-scrub covers
Juniper scrub communities (Juniperus communis alpina)
Erinaceae and puncture vine mid- and high-altitude scrub communities
Heterogeneous scrubs dominated by Dorycnium epntaphyllum, Coronilla minima, etc.
Scotch broom/common broom scrub communities
Esparto grasslands (Stipa tenacissima, Lygeum spartum) (High in Murcia)
Sub-xerophilic and xerophilic hawthorn scrub communities (Hippophäe rhamnoides, Rhamnus saxatilis, Rh.lycioides -this one does not develop in hyperarid areas)
Brushwood communities (plurispecific calcicole + thermophilic scrubs)
Balearic brushwood communities with Euphorbia dendroides
Bearberry communities (Arctostaphylos uva-ursi)
Lentiscus communities (Pistacia lentiscus)
Patches
Phlomis purpurea scrub communities
Gorse-like Leguminosae communities and similar species
Halohydrophilic scrub communities (salty soils: swamps, coastlines)
Gypsophilic scrubs and covers (high gypsum contents)
Mix of broom-like Leguminosae scrubs
Vegetation strips, mixed mesophilic hawthorn scrub communities and similar species (dominated by Rosaceae)
Mediterranean dwarf palm communities/brushwoods (Chamaerops humilis)
Cystus scrub communities in mountains
Cystus and broom-like scrubs, not necessarily in high mountain environments
Broom scrub communities
Salix spp. pl scrub communities
Bushes, strips, fences, scrub communities, scrub galleries, etc. frequently arranged in line
Rhododendron ferrugineum scrub communities
Furze mixed scrub communities (including furze-heather, furze-fern, furze-broom and furze-Cistus psilosepalus communities)
Thymus communities and other groupings with similar physiognomy

Scrub formations without any assigned strategy:

Heterogeneous scrub galleries
Rock scrubs (conglomerates, rocks)
Hyperxerophilic or thermoxerophilic scrubs and covers (severe drought conditions)
Hyperxerophilic/thermoxerophilic, gypsophilic, halophilic, psammophilic and other intrazonal scrubs and covers
Psammophilic scrubs and covers (sandy soil: dunes)
Other brushwoods
Other patches
Other intrazonal or similar scrubs
Other scrubs or non-intrazonal mixed covers

Grassland formations included in forestry map.
R = resprouting species; G = germinating species

Code	Formation	STRATEGY
1	Grassland/pasture	G/R
2	High-mountain pastures	R
4	Esparto grasslands	R
5	Reed beds	R
6	Fernery	R

References

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Paula S., Pausas J.G. 2009. BROT: a plant trait database for Mediterranean Basin spe-cies. Versión 2009.01. URL: http://www.uv.es/jgpausas/brot.htm.

ADDENDUM III
EMERGENCY ACTIONS TO CONTROL HILLSIDE EROSION

■ SEEDING

Seeding can be justified in forests (or hillsides) where slow recovery of the vegetation cover is expected and bearing in mind that water erosion is inversely correlated to the vegetation cover (Beyers, 2009). In forests where natural post-fire recovery of vegetation is insufficient, fast-growth herbaceous species which can reach high cover levels within a few months can be seeded, although avoiding the use of exotic species which could cause problems to natural regeneration.

Figure 1. Experimental seeding where different vegetation cover levels according to the actions undertaken can be observed: on the background, seeding + mulch, in the middle, mulching and on the foreground, seeding.

Priority areas/conditions for application

Action upon hillsides that also meet the following requirements must be prioritised:

- Risk of intense rainfall during the autumn.
- Soil prone to water erosion.
- Before the fire, under 30-40% of the surface was covered by resprouting plants.
- The fire severely affects the soil and the vegetation, not leaving any living plants and leaving approximately 30-40% of the ground uncovered (without any leaf litter, living vegetation or stone content cover). If there are trees in the area whose dead leaves have remained attached to the crown, we must bear in mind that such will eventually fall down and reduce the area of uncovered soil in the short term.
- Gradient between 15% and 65% (Napper 2006, Wagenbrenner et al. 2006).

Priority must also be given to specific areas where sediment generation could affect infrastructure or natural values:

- Slopes and embankments in traffic routes.
- River banks of significant value in terms of fauna and fish (it can be associated with environmental engineering actions).
- The potential erosion of the hillside compromises downstream ecological, social or economic values.

Alongside the technical and economic constraints of the treatment, others issues could be:

- There must not be endangered flora species, since they can be affected by other herbaceous species.
- According to Beyers (2009), the greatest risk is that seeding interferes with medium-term natural recovery of vegetation, thus reducing the survival or growth of sapling forests of scrub or tree species in the areas where seed regeneration is sought and planned. According to previous air-seeding experiences in the U.S., the mortality of sapling forests of indigenous scrub species starts to increase when herbaceous covers exceed 30%.
- If annual plants which wither in the summer are used, fire risks could increase.
- By using commercial seeds, there is a risk of bringing aggressive non-native species into the territory.

Species and density

According to Beyers (2009), the Western U.S. (where they wide experience in seeding), aggressive exotic gramineae, both annual and perennial, have been traditionally used, generally with densities of 400-600 seeds m^{-2} depending on their viability. In recent years, there has been growing interest in the use of indigenous species; Peppin et al. (2011) provide a full list of species used since the 1970s. In Spain, there has been a variety of applications (Chart 1).

Based on these experiences, the combination of gramineae and specially leguminosae is recommended, including both annual and perennial species. In the Spanish Eastern coast good results have been obtained by *Dactylis glomerata, Lolium perenne, Sanguisorba minor* and *Brachypodium retusum* as a result of their coverage capacity and by *Vicia sativa* as a result of its earliness (Bautista et al. 1997).

Application techniques

- Manual seeding: broadcast or using strips.
- Hydroseeding: a slurry of water, seeds and some soil conditioner (mulch) is pressure-sprayed onto the soil using a hose. It is only applicable to areas near a forest track.
- Air seeding: the weight of the seed conditions its effectiveness. Seeds can be pelleted.

Seeding can be carried out separately or together with *mulching,* fertilising, fixing agents, etc.

Chart 1. Post-fire emergency seeding experiences in Spain

Author	Province	Environmental conditions	Species	Dose
Bautista et al. (1997)	Alicante	semi-arid thermo-mediterranean climate, marly lithology	mix of gramineae and leguminosae that included both annual and perennial species: *Cynodon dactylon*, *Dactylis glomerata*, *Festuca ovina*, *Lolium perenne*, *Paspalum dilatatum*, *Phalaris canariensis*, *Medicago sativa*, *Lotus corniculatus*, *Onobrychis sativa*, *Sanguisorba minor* and *Vicia sativa*.	20 g m^{-2}
Bautista et al. (1997)	Valencia	dry thermo-mediterranean, argillites	*D. glomerata*, *C. dactylon*, *F. ovina*, *V. sativa* and *M. sativa*.	
Badia & Martí (2000)	Huesca	semi-arid meso-mediterranean, marls and gypsum	*M. sativa*, *Medicago truncatula*, *Onobrychis viciifolia*, *Vicia villosa*, *Agropyron cristatum*, *D. glomerata*, *Lolium rigidum* and *P. canariensis*.	30 g m^{-2}
Pinaya et al. (2000)	La Coruña	low mountain hyperhumid, granite	two different mixes: one with commercial seeds (*Lolium multiflorum, Agrostis capillaris* and *L. corniculatus*) and another with indigenous seeds (*Agrostis truncatula, A. capillaris* and *L. corniculatus*)	3000 seeds m^{-2}
Montávez et al. (2001)	Valencia	dry thermo-mediterranean, limestone-marl	mix of indigenous herbaceous and scrub species: *D. glomerata*, *Festuca arundinacea*, *L. perenne*, *Piptatherum miliaceum*, *O. sativa*, *V. sativa*, *Helichrysum stoechas*, *Cistus salvifolius*, *Anthyllis cytisoides*, *Coronilla juncea*, *Retama monosperma* and *Retama sphaerocarpa*	16500 seeds m^{-2}
Fernández-Abascal et al. (2003)	Leon	supra-mediterranean subhumid, siliceous substrate	(1) *Festuca rubra*, (2) *F. rubra* y *Lotus corniculatus*, (3) *Agrostis capillaris*, (4) *A. capillaris* and *L. corniculatus*. All of which have approximate densities of 20,000 seeds m^{-2}.	20000 seeds m^{-2}
Gimeno et al. (2005)	Alicante	dry meso-mediterranean, marl	mix of indigenous herbaceous and scrub species: *Brachypodium retusum*, *D. glomerata*, *Anthyllis vulneraria*, *Sanguisorba minor*, *Psoralea bituminosa*, *Hedysarum confertum*, *Dorycnium pentaphyllum*, *Rhamnus alaternus* and *Phillyrea angustifolia*.	5,000 seeds m^{-2}.
AVIALSA (2007)	Valencia		*B. retusum*, *Stipa tenacissima* and *Dorycnium hirsutum*	0.8 seeds m^{-2}
Vega et al. (2010), Fdez et al. (2012)	Pontevedra	hyperhumid low-mountain, schists and granites	*L. multiflorum*, *Festuca arundinacea*, *D. glomerata*, *F. rubra*, *Agrostis tennuis* and *Trifolium repens*	25-45 g m^{-2}
Cabrera (2010)	Zaragoza	dry meso-mediterranean, limestones	*Hordeum vulgare* and *M. sativa*	30 g m^{-2}
Díaz-Raviña *et al.* (2012)	Ourense	sub-humid mountain climate, phyllites	*Secale cereale*	10 g m^{-2}

The success of seeding depends largely on seed density (and quality), post-fire rainfall (total amount and intensity) and predation. Violent wind storms can redistribute the seeds on hillsides. Most seeds respond better when partially into the ground, but scarification is not advised in areas where erosion risks are high. Covering seeds with *mulch* can have the same effect and also prevent predation (Beyers, 2009). Oliveira et al. (2011) have observed that many used indigenous species germinate preferably and only during the autumn, which must be taken into account when planning actions.

Effectiveness

According to studies conducted in the U.S., a vegetation cover of 30% or higher starts to be partially effective to control water erosion, while 60% is required to be fully effective (Beyers, 2009). Nonetheless, only a third of seeding actions conducted in the U.S. reach 60% of cover during the first growing season. As a result, this technology is considered insufficient for immediate post-fire soil protection. As research on seeding progresses, evidence leads us to bring the effectiveness of this method into question (Peppin et al. 2010, Chart 2).

Chart 2. Effectiveness of emergency seeding in Spain (erosion rates are measured using several methods). Environmental conditions: Ar: argillites, Ma: marls, Ca: limestones, Es: schists, Gr: granite, HH: hyperhumid, S: dry, SA: semi-arid, SH: subhumid, Si: siliceous, Ye: gypsum. Time frames in months and years refer to the time elapsed since the fire. ns: not statistically significant

Test: environmental conditions, other treatments included	Herbaceous cover of sample soil	Increase of soil cover as a result of seeding	Erosion rate of sample soil (t ha^{-1} year^{-1})	Reduction of erosion as a result of seeding
Bautista (1997): S, Ma. Mulch and fertilising	50% (month 6-18)	15%	15-20	30%
Bautista (1997): SA, Ma. Mulch and fertilising	25-35% (month 6-18)	7% (month 6) 0% (month 18)	20-25	30%
Bautista (1997): S, Ar. Mulch and fertilising	<10% (month 3)	40% (month 3) 10-15% (month 12)	No data	No data
Badia & Martí (2000): SA, Ca	45% (year 1) 57% (year 2)	30% (year 1) 0% (year 2)	1.8	50%
Badia & Martí (2000): SA, Ye	16% (year 1) 27% (year 2)	30% (year 1) 0% (year 2)	3.6	67%
Pinaya (2000): HH, Gr	40% (month 10)	+30-35% (month 10)	0.8	85%
Fdez-Abascal (2003): SH, Si	<1% (month 1) 20% (year 1) 50% (year 2)	10% (month 1) 15-35% (year 1) 0% (year 2)	No data	No data
Gimeno (2005): S, Ma	34% (month 14)	5% (ns)	>10	ns
Vega (2010): HH, Gr. Prescribed burning	60% (month 8)	10% (ns)	4.7	20% (ns)
Díaz-Raviña *et al.* (2012): SH, phyllites	No data	No data	6,6 (month 4)	37%
Fernández (2012): HH, Es	36% (month 9)	12% (ns)	No data	ns (month 9)

■ POST-FIRE MULCHING

As seeding, mulching aims to reduce soil losses as a result of erosion in burned hillsides during the period when vegetation cover is insufficient.

Mulching covers the ground, protecting it from rainfall impacts, increasing infiltration and hindering run-off flows. It can also contribute to the recovery of the vegetation cover by protecting seeds and improving the edaphic microclimate. As a result, in addition to protecting the soil from erosion, mulching improves water contents in upper soil horizons, which can reduce soil crusting and contribute to the establishment of vegetation (Bautista et al., 2009).

Priority areas/conditions for application

Action upon hillsides that also meet the following requirements must be prioritised:

- Risk of intense rainfall during the autumn.
- Soil prone to water erosion.
- Before the fire, under 30-40% of the surface was covered by resprouting plants.
- The fire has severely affected the soil and the vegetation, not leaving any living plants and leaving approximately 30-40% of the ground uncovered (without any leaf litter, living vegetation or stone content cover). If there are trees in the area whose dead leaves have remained attached to the crown, we must bear in mind that such will eventually fall down and reduce the area of uncovered soil.
- Gradient over 15% and under 65% (Napper, 2006; Wagenbrenner et al., 2006).
- If mulching is made from light materials, the hillside must not be exposed to strong winds, since such could redistribute the materials across the surface as it occurs in hilltops. This problem can be corrected, for example, by punching straw mulch into the floor (Bautista et al., 2009) or covering it with trunks or branches.
- No endangered species must be affected by mulching.

It must also be a priority in areas where sediment generation compromises downstream ecological, social or economic values.

Materials and quantities

Mulching can be applied in dry form or mixed with water *(hydromulch)*. In such case, bonding agents such as wood fibre or chemical polymers (polyacrylamides) can be added. In Spain, a wide range of different materials have been used up to the present date (Chart 3). On a general basis, it must always be preferable to use materials from the burned forest itself, particularly ground burned debris.

When it comes to quantities, Napper (2006) estimates that 2.2-4.5 t ha^{-1} of cereal straws provide 70-80% of soil cover with a 2.5-5 cm thickness.

Chart 3. Post-fire mulching experiences in Spain

Author	Province	Environmental conditions	Material	Quantity
Bautista et al. (1996)	Alicante	thermo-mediterranean semiarid, marls and limestone colluvium	Barley straw	2 t ha^{-1}
Badía & Martí (2000)	Huesca	semi-arid meso-mediterranean, marls and gypsum	Barley straw	1 t ha^{-1}
Montávez et al. (2001)	Valencia	dry thermo-mediterranean, limestone-marl	- Municipal solid waste compost - Waste water treatment sludge - Grape marc - Ground pine cones	No data

			- Peat - Cereal straw and coconut fibre blanket	
Gimeno et al. (2005)	Alicante	dry meso-mediterranean, marl	Ground pine tree forest debris	No data
AVIALSA (2007)	Valencia		Hydromulch made of organic fibres, dye and an undetermined fixing agent	No data
Fernández et al. (2011, 2012)	Pontevedra	low mountain hyperhumid, schists	Wheat straw	2.5 t ha^{-1}
Fernández et al. (2011)	Pontevedra	low mountain hyperhumid, schists	Ground forest debris	4 t ha^{-1}
Vega et al. (2010)	Pontevedra	low mountain hyperhumid, granite	Straw	2.3 t ha^{-1}
Cabrera et al. (2010)	Zaragoza	dry meso-mediterranean, limestones	Chipped pine wood	25 t ha^{-1}
Díaz-Raviña *et al.* (2012)	Ourense	Sub-humid mountain climate, phyllites	Wheat straw	2.5 t ha^{-1}
Martins *et al.* (2012), Prats *et al.* (2012)	Baixo Vouga	meso-mediterranean humid, schists	Non-ground wood debris	13,6-17,5 t ha^{-1}
Prats *et al.* (2012)	Baixo Vouga	meso-mediterranean humid, schists	Ground *Eucalyptus* bark	8.7 t ha^{-1}

Application techniques

Manually, whether across the whole area or by strips at different levels: according to Bautista (2009), strip mulching in the U.S. involves applying the mulch in separate 10-30 cm strips covering half of the area.

*Using a nozzle: to spray *hydromulch*. It is only applicable to areas near a forest track.

*Application area. Using helicopters and later finishing off the work on the ground.

Mulching can be applied separately or combined with seeding, although the level of global ground cover must be at least 50-60% according to Bautista et al. (2009) or 60-80% according to Robichaud et al. (2010); in any case, the amount of mulching applied is relevant.

Figure 2. Burned wood debris that constitutes protection mulch.

Effectiveness

Mulching allows the immediate increase of the ground cover. Studies conducted in the U.S. have found evidence proving straw and chipped wood effective, provided that they are applied on adequate areas and taking the necessary measures to prevent subsequent redistribution (Bautista et al., 2009; Robichaud et al., 2010; Chart 4). This positive impact comes when most needed: during the first growth period when there is still little natural vegetation cover.

Effectiveness depends on the global level of ground cover. The type of materials used is also relevant, even though there are not enough studies comparing materials.

Effectiveness also depends on a homogeneous application and therefore on the application technique used. It is important that mulch stays on the ground for the whole first and second years. Processes that may redistribute mulch upon the hillside could impair its effectiveness, such as the wind.

Mulch effectiveness decreases in inverse proportion to rainfall intensity. In the U.S., evidence has been found of the ineffectiveness of mulch for rainfalls with intensities corresponding to a return period of 5-10 years (Bautista et al., 2009).

Excessive thickness constitutes a significant risk that could hinder the development of sapling communities. Robichaud (2000) found that the germination of scrubs occurred where thickness was less than 2.5 cm. The goal of mulch is to provide the ground with temporary protection while the vegetation recovers a cover level that will enable the cover to protect the ground. This is why it is important that mulch does not interfere with plant regeneration. Another risk is the introduction of non-native species alongside with straws.

Studies that combine seeding and *mulching* show on a general basis that *mulch* reduces erosion but seeding does not bring about any additional improvement (Robichaud et al., 2010).

As for *hydromulch* (mulch+fixing agent+water), results in the U.S. suggest that it resists the wind and the impact of rain drops but that it is quite ineffective against run-off, so its use is only advised for forest track banks where upstream run-off is not likely to occur. Sandy soils near roads have also been used (Robichaud et al., 2010).

Chart 4. Effectiveness of post-fire mulching in Spain (erosion rates are measured according to several methods), ns: not statistically significant

a The wind removed most of the mulch by mid-treatment

Test: other treatments applied	Mulch cover (%)	Erosion rates of sample soil (t ha^{-1} year^{-1})	Reduction of erosion rates as a result of mulching	Impact on vegetation
Bautista et al. (1996)	80%, adding mulching and vegetation (years 1, 2)	0.76	86%	Slight increase in ground cover
Badia & Martí (2000): with seeding	15-45% (years 1, 2) 100% adding mulching and vegetation	Approx. 1	46% (year 1)	- Cover: ns - Biomass: increase (year 1)
Gimeno et al. (2005)	50% (months 6, 18)	>10	100%	ns
AVIALSA (2007): with seeding	No data	No data	65%	Improvement germination
Fdez et al. (2011): straws	80% (month 0)	35	66% (year 1)	ns
Fdez et al. (2011): wood chips	45% (month 0)	35	ns (years 1-2)	ns
Fdez et al. (2012): straws, with seeding	Increase ns (month 9)	No data	ns	ns
Vega et al. (2010)	No data	4.7	90% (month 9)	ns
Cabrera et al. (2010)[a]	77% (month 0)	3.6	22% (month 6)	No data
Díaz-Raviña *et al.* (2012)	No data	6.6	89% (month 4)	No data
Martins *et al.* (2012)	80% (month 0)	13.6	90% (year 1)	No data
Prats *et al.* (2012): waste	76% (month 0)	0.3	0% (year 1)	No data
Prats *et al.* (2012): bark	67% (month 0)	5.4	86%	No data

■ EROSION BARRIERS

Erosion barriers are used to reduce run-off and sediment transport in burned hillsides, to foster water infiltration and sedimentation on the same hillside from where they have been extracted. The construction of barriers transversally to the maximum slope line can slow down flows, create stagnation areas and store sediments generated upstream.

Log erosion barriers and **branch bundles (wattles or fascines):** the former ones are emergency actions against hillside erosion and the latter are mainly a way to manage burned timber. Both treatments can be combined into the same structure.

The third type are **check dams** or **correction dams,** which are structures built across a water course to correct water flow channels (thalwegs, gullies, etc.). These are explained in the next section.

Priority areas/conditions for application

Action upon hillsides that also meet the following requirements must be prioritised:

- Risk of intense rainfall during the autumn.
- Soil/Lithology prone to water erosion.
- Before the fire, under 30-40% of the surface was covered by resprouting plants.
- The fire has severly affected the soil and the vegetation, not leaving any living plants and leaving approximately 30-40% of the ground uncovered (without any leaf litter, living vegetation or stone content cover). If there are trees in the area whose dead leaves have remained attached to the crown, we must bear in mind that such will eventually fall down and reduce the area of uncovered soil.
- Gradient over 15%.

It must also be a priority in areas where sediment generation compromises downstream ecological, social or economic values.

Its use is especially interesting in hillsides where there used to be trees before the fire. In this case, the use of trunks to build barriers is a method to prevent erosion and, at the same time, a way to handle burned timber. In addition, trunk bases can be used to anchor the barrier, as long as it does not affect the effectiveness thereof.

Materials

- Felled trees. In the U.S., each barrier is usually built out of one single trunk, even though sometimes more are used to increase the volume of retained water. In such case, sealing is not only required between the lower trunk and the ground, but also between the different trunks used.
- Straw wattles/biorolls (cylinders of compressed straw).
- "Infiltration trenches", built in discontinuous ridges in level lines.
- Straw bale strips.

Application techniques

For the creation of infiltration trenches, furrows are made on level lines, alongside a downhill ridge.

In all the other cases, the barrier is arranged perpendicularly to the maximum slope line or in "V" (otherwise, instead of retaining the flow they just redirect it or even impound it). The barrier is attached to materials sticking out of the terrain (outcrops, stumps or standing trees, etc.) or to pegs (anchoring is highly relevant for the durability of the structure). Then, the space between the terrain and the barrier is sealed with soil (barrier-soil contact is essential for the barrier to be effective). A small furrow is made upstream from the barrier and all along the barrier to increase its capacity to impound water and sediment. Finally, a soil and stone ridge can be built to each end of the barrier to avoid water overflowing the sides and at the same time to increase the barrier's storage capacity.

No recommendations with regard to the height or length of barriers have been found, but barriers executed with trunks or trenches in the U.S. mostly have a theoretical sediment storage capacity of 48-73 t ha^{1}, achieved by means of densities of 46-175 trunks ha^{-1} (Robichaud et al., 2010).

Barriers must be distributed in a staggered manner, covering the gap left by uphill barriers and preventing the existence of uninterrupted routes for run-off flows. Based on the wattles analysed by Gimeno et al. (2008) in Castellón, 40-50 fascines ha^{-1} and 300 linear metres ha^{-1} managed to interrupt water flow within 25 metres in 70% of the cases, and in the remaining cases uninterrupted water flow was 40 m at most.

Special attention should be given to the installation of barriers on the spots most sensitive to soil erosion: discontinued soil that could store run-off, areas with symptoms of prior erosion, problematic areas near forest tracks, etc.

Effectiveness

According to the studies conducted in the U.S., the effectiveness of erosion barriers is restricted to the first rainfall episodes (Robichaud et al., 2010). These authors also report that this effect could be caused, to a certain extent, by the fact that the very construction of barriers implies certain impact on the ground which increases the amount of easily eroded sediments. These studies also report that barriers are effective when rainfall intensity is low but have no impact when rainfall episodes are intense.

In conclusion, the effectiveness of a barrier is thought to depend on the volume of sediments that it is capable of storing. As the barrier becomes plugged, the amount of sediments it can store diminishes. In many cases, it cannot store more than 60-70% of the theoretical storage capacity (Robichaud et al., 2010).

As far as it is known, the application of erosion barriers in Spain has not been under study. In all references reviewed, the main goal was to manage burned timber. Navarro (2005) proposes the use of log wattles (with several layers) filled up with branches to fight erosion, but there is no evidence that this method will have a significant impact. The wattles under study by Gimeno et al. (2008) in Castellón were conducted according to similar criteria to those applied by Navarro (2005), without sealing the gap between the floor and the log.

Fernández et al. (2011) applied in Galicia branch strips in contour lines, anchored to the floor but permeable, arranged in a continuous manner but with a 10-m gap between strips, so the ensemble of strips took up 6% of the total surface. No significant impact on the erosion rate was found during the first year after the fire in an area with soil losses of 35 t ha^{-1} $year^{1}$.

Finally, Copano et al. (2007) proposes the use of wood logs of 7-10 cm of diameter, for densities of 570 barriers ha^{-1} and 2300 linear metres ha^{1}, filled upstream with soil so as to conduct planting activities in gradients over 50%.

Figure 3. Erosion barrier

Check dams

Check dams are transversal structures built across water courses to correct flow channels that carry water streams in the hillside: thalwegs, rills, gullies, etc. (secondary drainage network). Correction structures for stream channels and ravines (main drainage network) are not included in this category, since they require major works, such as dikes. These major structures are listed in the Inventory of available technologies in Spain for the fight against desertification[14].

In hillsides affected by fire, run-off is more likely to reach the surface drainage network and the outlet area of the basin. The construction of barriers crossing the channels that carry the water flows in the hillside and the staggering of slopes can help slow down run-off and favours the deposition of coarse sediment. These structures also help reduce the sediment exports outside the hillside, they contribute to water infiltration and lessen the impact on downstream infrastructure and natural sites.

On the other hand, the deposition of soil and ash can form a "fertility island" that could be reforested once it is clogged.

Priority areas/conditions for application

- This action should be performed upon hillsides meeting the following requirements:
- Showing signs of erosion activity prior to the fire, and

[14] http://www.magrama.gob.es/es/biodiversidad/temas/desertification-y-restauracion-forestal/lucha-contra-la-desertificacion/lch_inventario_tec.aspx

- Run-off flows cross infrastructures that lack adequate drainage structures, or they are located upstream from significant natural, social or economic sites which the generation of post-fire sediment could jeopardise.
- Materials

Several construction types have been proposed:

- Revetment with felled trees, anchored to natural structures or to pegs (Ruiz & Luque, 2010).
- Dry stone walls, stone walls or small gabions (for example, 2x1x1 m), as long as there is available stone nearby.
- Mesh and geotextile barrier anchored to pegs (De la Fuente & Blond, 2010).
- Revetment of straw bales, anchored to pegs (Napper, 2006).
- Tardío & Caballero (2008) designed dikes mixing masonry and wood debris made up by two log fences anchored to pegs. The logs and pegs are tied down using a rope, which is also used to anchor fences to natural structures. The gap between the fences is filled up with wood debris. The structure is stabilised upstream and downstream using stone slope 2:1. See Technology Inventory Card: "Design of transversal works: mixed masonry and residual biomass dikes".

Figure 4. Burned timber management in the riber bed and the slopes of a small ravine

Execution

The elements in the revetment must be well anchored to each other and to natural structures. For this purpose, ropes must be used. An adequate sealing of the revetment base is essential so water does not flow underneath it and remove pegs out of it, as well as the attachment to the channel walls. A spillway must be constructed so as to avoid uncontrolled overflow.

Upstream, the check dam can be partially filled up with soil, stones or branches so as to avoid the damages caused by large items dragged by run-off flows. The check dam can also be reinforced downstream using large rocks or logs in case it cannot bear the weight of water and the accumulated sediment by itself.

On erodible soils, the fact that water heads can intensify erosion along the downstream sections must be taken into account. To alleviate the impact of such, an energy dissipation structure can be constructed under the spillway using logs or rocks. This intervention can also be designed as a set of several check dams instead of a single one.

According to Napper (2006), check dams are more effective if several are arranged in series instead of being isolated. It is recommended to build the first one at a spot still unaffected by headward erosion, where the river bed is still stable. The following dams (downstream) can be arranged so the base of the first one is at the same level as the top of the spillway of the next one (as long as slopes are not particularly steep). It is recommended to find solid natural anchorage points, gentle slopes and stable channel walls.

Copano (2007) proposes to partially fill up check dams with soil and plant vegetation on them.

Effectiveness

Napper (2006) believes that check dams are more effective in small-sized river basins (under 2 ha), at the upper part of the basin and in gentle slopes. In any case, these actions do not keep the soil in its original position in the hillside. Instead, they just prevent them from being conveyed outside the basin.

■ OTHER POSSIBLE EMERGENCY ACTIONS

- Fertilisation (organic matter, municipal solid waste compost): to improve seeding or natural regeneration using seeds or resprouting (Vázquez et al., 1996; Villar et al., 1998; Guerrero et al., 2001; Meyer et al., 2004)
- Enclosures to keep grazing/wild fauna away.
- Coppice of *Quercus* (Cardillo & Bernal, 2003; Gil Guzmán, 2006).
- Reconstruction of walls in terraced hillsides.
- Correction of gullies/rills by means of earth moving or stone filling.
- Chemical treatment of the surface using polymers such as polyacrylamides (PAM). These products have been used to avoid sealing semi-arid soils (Ben-hur, 2006). Martins *et al.* (2012) used PAMs in Portugal (by themselves, not mixing them with mulch) for the purpose of reducing post-fire erosion, but it did not have any significant impact; their conclusions match those by Robichaud et al. (2010) in the U.S. Darboux *et al.* (2008) suggest their use in embankments and trails combining it with seeding for the purpose of improving germinating and growth conditions. Section 3.2, Post-fire Mulching, elaborates on the use of these components as well as the use of *hydromulch*.
- Rehabilitation of pastures.
- Scarification of physical soil crusts.

We recommend to check the "Inventory of available technologies in Spain for the fight against desertification"[15], where the most recent proposals regarding materials and construction types are listed. Both in regard to Works correcting flows and hillsides and to the Stabilisation of embankments, technologies that can be applicable to the reduction of post-fire erosion processes are included, such as:

- Use of fascines to control hillside and embankment erosion
- Use of wattles/biorolls to control erosion
- Use of brushwood and living material fills to repair wanes and gullies
- Use of brushwood blocks to control erosion in hills and banks
- Grid division to control erosion and other applications
- Meshes and networks to control erosion and other applications
- Organic blankets to control erosion
- Hydroseeding for soil preservation
- Mulching for erosion control

In Vega et al. (2013) there is a detailed list of techniques applied in Galicia.

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[15] http://www.magrama.gob.es/es/biodiversidad/temas/desertificacion-y-restauracion-forestal/lucha-contra-la-desertificacion/Lch_inventario_tec.aspx

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