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CORPO FORESTALE
DELLO STATO

Evaluation of forest fire damages in Italy

Edited by

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Accademia Italiana di Scienze Forestali
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INDEX

PREFACE

The forest fires emergency, occurring regularly each year at national level and calling for a focused action of civil protection, rises some reflections.

The attention towards the environmental problems, especially the perception of the forest as an essential element of life quality, has grown. The result is a vision of the problem not only limited to a situation of personal risk but broader and comprising the concerns for the huge damages of forest fires occurrence on natural balances.

Forest fire in Italy has reached the level of a real disaster and induces in the citizens a sense of malaise, causes destruction and death of plants and animals and highly reduces the degree of environmental safety.

The forest was, and still is, an essential component of the economy of the populations, rural and not, although its role has been highly renovated due to the nowadays prevailing ecologic and environmental meaning.

The damages caused to the environmental heritage by huge forest fires destroying thousand hectares of wood and non wooded land in our Country are very relevant.

The economic evaluation of the related damage is one of the essential elements to establish an "environmental accounting" to drive into concrete categories the environmental effects of certain aggressive and destructive actions.

This study prepared by the Italian Academy of Forest Sciences together with the Italian National Forest Corp has allowed to find estimate models through parameters to economically and quickly quantify in a detailed way the damages arising from forest fires.

This is an innovative work, fruit of a careful scientific research, of experience and land knowledge, and also a useful tool to agree homogeneous operative protocols to support the work developed by people who contribute to the protection of the forest resources.

Paolo De Castro
Minister for Agriculture
Food and Forest Policies

INTRODUCTION

The recurrent summer question of fires causes serious problems to the Italian forests and to the rural world and promotes huge social concerns.

Actually the environmental damages are very relevant and visible, as underlined also by the mass-media: it is not, anyway, possible to explicate these events only in relation to arson or social changes. The causes are quite complex and the solutions have to be proposed on the basis of a complete knowledge of causes, prevention, fire extinction, investigation, monitoring and evaluation of the effects. The last ones are, unfortunately, often heavy and quite long-lasting on forest ecosystems.

The Italian National Forest Corp has evolved and adapted its structure during the years. It aims to support fire suppression, to establish a cadastre of burnt areas and to repress the causes by the use of innovative technologies and methods.

This document, as the result of a fruitful collaboration with the Italian Academy of Forest Sciences, is focused on the global economic evaluation of the damages caused by fires: therefore it aims to satisfy the need of a scientific and pragmatic environmental accounting.

Forest and environment protection overlap with the protection of the mankind and this protection requires also the right consideration of all the services offered by the forests to the communities. It is, anyway not easy to economically estimate them as these services are usually "not marketable". *On the other hand the evaluation of the economic damage due to forest fires represents anyway, a prerequisite for a complete, updated and reliable forest ecosystems monitoring.*

The translation of the damages from forest fires into economic values represents therefore the basis to enable the formulation of coherent decisions and solutions: between them, the adoption of the adequate measures against fires and the provision of significant financial resources need to be stressed.

Cesare Patrone
Head of the Italian
National Forest Corp

FOREWORD

In Italy forest fires are calamities that significantly impact the country's forests with tens of thousands of hectares burned every year. In the European region the annual emissions estimated from wildfires are 11 million tons of CO_2. In spite of this, there is very little information concerning actual economic damages caused by different types of forest fires. This shortcoming hinders decisions concerning investments for the adoption of adequate fire-prevention and fire-fighting measures and hence of the allocation of adequate resources. Only an assessment of actual environmental and economic impacts of fire damages can provide a rational basis for determining appropriate investments in defensive and restoration efforts.

The aim of this paper is to present a summary of the operational methods for economic assessment of damages to the products and services which characterize forests stricken by fire, as well as the costs of fighting fires. The methodology was set up upon request of the *Corpo forestale dello Stato* (National Forest Corp) and will be applied in the future in monitoring and in supporting forest and environmental statistics in Italy. Hopefully a similar methodological approach could be extended to other Countries, especially those with similar forestry characteristics, to allow comparison and integrated evaluation of fire damage costs.

Orazio Ciancio and *Piermaria Corona*
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ACRONYMS AND SYMBOLS

BEF	Biomass expansion factor
C	Carbon
€	Euro
GPS	Global Positioning System
ha	Hectare
l	Litre
MAV	Mean Agricultural Value
m^2	Square meter
m^3	Cubic meter
NWFP	Non-Wood Forest Products
r	Discount rate
t	Metric ton

1. METHODOLOGICAL FRAMEWORK

The environmental and social impacts from forest fires have been analyzed by many Authors as regards monitoring, restoration and reconstruction aspects (e.g.: TRABAUD, 1989; CIANCIO *et al.*, 1996; JOHNSON and MYANISHI, 2001; ARROWOOD, 2003; BARBOSA *et al.*, 2004; BLASI *et al.*, 2004). Not always, however, can knowledge on environmental damages, social impacts and technical-organization aspects of fire fighting be readily translated into economic-financial assessments. A correct estimate involves the evaluation of two main components of economic damage:

- the cost related to the decreased value of the damaged asset (that is the loss of products and services it provides);
- the fire suppression costs incurred by public and private agencies.

Moreover, in case of large and severe events, some general costs, normally external to the damaged site, may occur like loss of public and private assets, temporary or permanent disability and, in extreme cases, loss of life, roadblocks, blackout in communication, and other impediments to use infrastructures.

Several authors (e.g.: VAUX *et al.*, 1984; FLOWERS *et al.*, 1985; MARCHETTI and PETTENELLA, 1994; ENGLIN *et al.*, 2001) have considered methods for the financial assessment of the first of the two components of damage which is of fundamental importance and involves greater problems in evaluation. These problems have increased in recent years, at least in Italy: in the past loss in timber production was the highest item (and often the only one) on the damage scale. Under current economic conditions, the commercial value of damaged wood products has limited importance if compared with the costs related to loss of public non-market services (i.e. biodiversity protection, water cycle regulation, supply of recreational areas, soil protection, carbon sequestration, etc.). Furthermore, the costs related to these services are difficult to standardize or generalize (e.g.: IIED, 2003; AYLWARD, 2004; MERLO and CROITORU, 2005).

The costs of fire suppression, for which better accounting documentation is normally available, are much easier to be determined and calculated.

When fires occur, the authorities responsible for surveying the damage have other various, urgent operational and administrative tasks and duties. It is understandable that, in these situations, forest authorities tend to favour rapid and simplified procedures for damage assessment.

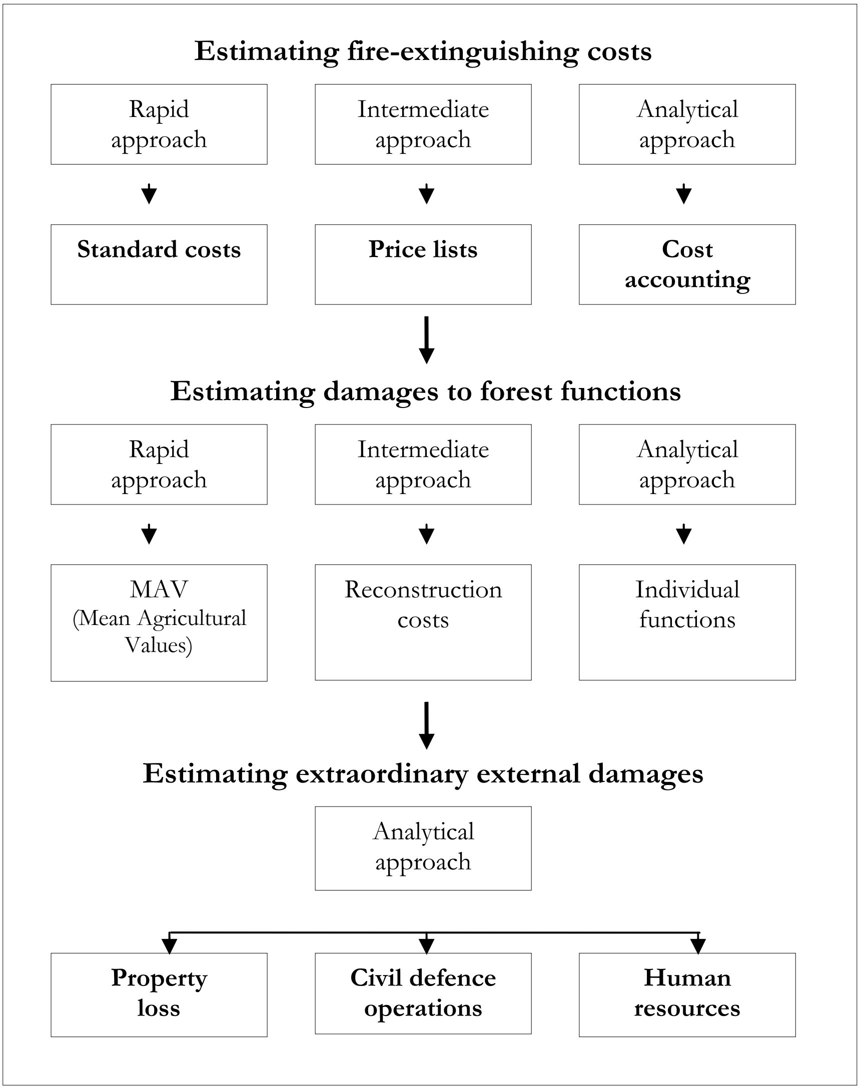

Figure 1 – Modular methodology for assessing damage from forest fires.

Estimating costs of extinguishing a forest fire can be simplified through the use of pre-defined lists of standard costs and prices, but assessing the value of the lost products and services cannot be based on standard values, since they are generally highly site-specific (see the forest types, management methods and hence quantity and price of products and services, also in relation to accessibility and users).

Taking these problems into account, this document describes a forest fire damage evaluation method based on sequential levels of complexity using a modular approach (Figure 1), in relation to damage severity. The methodology was developed to answer a request by the Italian National Forest Corp who is in charge of providing official data on forest damage costs to the National Institute of Statistics and of monitoring forest fire occurrence at country level. Specifically, the damage evaluation can be divided in three components:

- costs of extinguishing fires concerning machinery, equipment and personnel engaged in active fire fighting (§ 2);
- environmental damage, relative to the loss of products and services, with and without markets (§ 3);
- damages to persons and infrastructures and general organizational expenses related to civil defence operations (§ 4).

2. FIRE SUPPRESSION COSTS

Costs for extinguishing forest fires can be broken down into two components: the general costs for forest monitoring and fire prevention and the site-specific, variable costs of fire fighting related to each intervention. The first component includes:

- costs of creating and running some infrastructures as operations centres and radio networks, lookout towers, water supply points, monitoring equipment (like remote sensing systems), etc.;
- ordinary maintenance costs of the ground equipment and aircraft;
- personnel costs selection and training and purchase of individual protective equipment, both for professional fire-fighters and volunteers employed in forest monitoring.

The general fire-prevention costs cannot be attributed to the personal responsibility of the individual who started the fire: therefore, even if they are economically significant, they are not included in this methodological proposal which focuses on the evaluation of fire damage costs.

The second component (the costs of active fire-fighting) is highly variable. In general, these costs are not proportional to the value of the forests: in case of no intervention they may be zero; on the other hand, fire extinction for example in an inaccessible artificial pine forest may incur in very high costs, even if the area is of little ecological and productive value. Fire extinguishing costs can be estimated by three procedures:

- ordinarily, we can proceed with rapid approaches based on standard costs with no reference to the real operating time (§ 2.1);
- for operations of a certain magnitude and complexity, we can refer to standard costs per hour related to the real operating time of equipment and personnel engaged in fire fighting (§ 2.2);
- for very large events, where the fire-fighting, in addition to being particularly expensive, involves extraordinary use of vehicles, equipment and personnel, we can use analytical approaches based on specific accounts of times, costs, and types of equipment and personnel (§ 2.3).

2.1. RAPID APPROACH: STANDARD COSTS

For very rapid estimates of suppression costs of small fires (with a duration of less than ten hours) we propose making reference to two different methodological approaches: the first is based on standard costs of personnel engaged in the fire-fighting, the second on different types of operation crews.

2.1.1. Rapid approach with reference to standard personnel costs

For events of limited size, with less than two hours needed to put out the fire (30-40% of the events in Italy) the evaluation can be based on the assumption that the personnel remains at the operations site for the duration of the event plus the time needed to get to the operations zone.

The cost of extinguishing the fire (C_{fe}) can be estimated if we know the mean hourly cost of personnel (C_{mh}), the number of persons who participated (N_{tot}), possibly broken down into paid and unpaid (N_{un}) personnel, and the duration of the operations to put out the fire (D), to which we add the costs of the equipment used: these can be assumed to be approximately equal to the cost of the personnel involved. It is obvious that unpaid personnel (e.g. volunteer workers) cannot be counted in calculations of the personnel costs and only the equipment costs should be accounted. Therefore, the estimate can be made on the basis of the following formula:

$$C_{fe} = ((N_{tot} * 2) - N_{un}) * D * C_{mh}$$

where:
C_{fe} = cost of extinguishing the fire (€); N_{tot} = total number of persons who participated in putting out the fire; N_{un} = total number of unpaid persons who participated in putting out the fire; D = duration of the operation, including the time needed to get to the operations zone (hours); C_{mh} = mean hourly cost of paid personnel (€/hour).

The number of hours needed to put out the fire (D) and the personnel involved (N_{tot}, N_{un}) are variables that can be easily obtained through a field survey for some typical events. In Italy the hourly cost of paid personnel (C_{mh}) can be assumed to be 18 €/hour; the incidence of costs for equipment and vehicles used by crew member can be considered equal to the cost of the personnel. When aircraft are used, they must be added to the ground crew costs.

2.1.2. Rapid approach with reference to standard crew costs

For operations lasting from two to ten hours (over 50% of the events in Italy) the extinguishing costs (C_{fe}) can be estimated by taking the mean hourly costs for each type of crew (C_{cr}), multiplied by the number of hours of the operation (D). Costs of any earthmoving equipment and aircraft (C_m) should be added to the standard costs of employing the various types of crews. The following formula can be used:

$$C_{fe} = C_m + \sum_{1}^{ns} (D \geq * C_{cr})$$

where:
C_{fe} = cost of extinguishing the fire (€); D = duration of the operations (hours), including the time needed to get to the operations zone; C_{cr} = mean hourly cost of the crew (€/hour); C_m = cost of earthmoving equipment and aircraft (€); *ns* = number of crews involved.

A possible classification of the main types of crews is based on two criteria: the type of fire-fighting equipment and the personnel employed. On the basis of these two criteria, we have defined the following system for classifying crews for the Italian context:

- Type A: light crew with unequipped vehicle (without extinguisher); these are fire suppression crews with light (manual or powered) equipment which provide support to other types of crews; they consist of 3-4 members and a crew chief;
- Type B: crew with light vehicle (equipped with extinguisher); consisting of 2 members and a crew chief on an equipped vehicle with a total weight of ≤3,5t;
- Type C: crew with heavy vehicle (equipped with extinguisher); consisting of 3-4 members and a crew chief on an equipped vehicle with a total weight of >3,5t;
- Type D: crew with unequipped vehicle; these crews are equipped with portable pumps for setting up hose lines; they consist of 3-4 members and a crew chief on vehicles equipped with power pumps, hoses and mobile tanks;
- Type E: light helitack crew; consisting of 3-4 members and a crew chief equipped with manual or powered equipment (chain saws, blowers, etc);
- Type F: helitack crew with fire-fighting module; consisting of 3-4 members and a crew chief equipped with manual or powered equipment.

Table 1 shows approximate hourly crew costs (C_{cr}) that may be used in estimating the costs of extinguishing a fire.

Table 1 – Hourly fire-extinguishing costs by type of crew in Italy.

Type	Mean cost (€/hour)
Type A – Light crew with unequipped vehicle	130
Type B – Crew with equipped light vehicle	100
Type C – Crew with equipped heavy vehicle	180
Type D – Heavy crew with unequipped vehicle	150
Type E – Light helitack crew	90*
Type F – Helitack crew with fire-fighting module	105*
Earthmoving equipment	50-150

(*) cost of transporting by the helicopter not included

When aircraft are used, the costs shall be added to the costs of the ground crews. The data shown in Table 2 can be used for estimating the costs of aircraft operations.

Table 2 – Costs of aircraft used in fire-fighting operations in Italy.

Type of aircraft	Name	Mean cost* (€/hour)	Mean fuel consumption** (l/hour)
Airplane	Canadair	8,000	1,200
Helicopter	NH 500	700	100
Helicopter	AB 412	2,500	500
Helicopter	S64 F	3,600	2,000

(*) costs include depreciation, insurance, maintenance, wear materials (other than fuel) and spare parts, personnel (only mission and overtime costs)
(**) mean price of aviation fuel (June 2007): 0.80 €/l

2.2. INTERMEDIATE APPROACH: USE OF PRICE LISTS

According to widely used accounting procedures, it is possible to make reference to standard prices lists defined for estimating the unit costs of personnel and equipment used in fire-fighting operations. These price lists have different purposes: cost estimates for statistical purposes and compensation procedures; internal accounting analyses used also for setting up tenders, reimbursement of volunteer personnel and suppliers. Clearly defining the various costs makes it possible, for example, to assess whether the operations costs are congruent to the context and, through simulations, to evaluate alternative methods of fire-fighting that may be more efficient.

The price lists are prepared on the basis of calculations of fixed and variable costs of the machinery, a commonly used procedure in industries for planning and managing equipment use. These costs may be determined as average values deriving from *ex post* accounting or during the equipment's service life. In the first case the calculation is based on experience-based data. In the second the calculation is based on real data (which, of course, must be systematically recorded during the service life of the equipment) and they are strongly influenced by the actual operating conditions; when forest fires are limited and/or forest equipment is not fully employed, real unit costs may be higher than the standard ones.

Even average values deriving from *ex post* accounting are not always easy to be defined: many different types of ground vehicles and aircraft are normally used, especially in a country like Italy where fire fighting is based on a rather decentralized system. For example, equipped vehicles present many different features according to vehicle type (there are many models of off-road vehicles), equipment type (equipment of varying size, different components, industrially or artisan-manufactured, or assembled by the final user) and the various vehicle-equipment combinations (fixed or mobile equipment, pumps with autonomous motors or powered by the vehicle engine, etc.). Another problem in standard price definition is related to the way the vehicles and equipment are used: not always are they dedicated exclusively to fighting forest fires. Often the fire-fighting equipment is dismantled at the end of the "fire season" and the vehicles are used for civil defence operations or for transporting materials for farming and forestry work.

A price list of approximate operating costs, broken down by macro-category of equipment used in fire-fighting operations, is provided in Table 3.

2.3. ANALYTICAL APPROACH: COST ACCOUNTING

For fires which are particularly significant in terms of operational costs and where we need a high level of accuracy in assessing the damage costs, it is possible to refer to the operating costs actually incurred. From the accounting system of the organisation mainly the variable costs will be carefully evaluated, since the fixed costs are evenly distributed over the mean service life of the equipment or personnel. Thus, for example, instead of considering the number of flight hours and the hourly cost according to the data on the standard price list, when estimating the cost of aircraft, we will refer to real data on consumption of fuel, retardant and other materials. In general this procedure does not greatly improve the accuracy of the estimate but only provide figures of less uncertainty.

Obviously, when the fire-fighting operation involves different organizations with their own, independent accounting systems, references to specific accounting can become extremely laborious and hence are only justified for cost evaluation of very large operations.

Table 3 – Approximate operating costs in Italy of equipment used in fire-fighting operations broken down by macro-category.

Equipment	Operating cost (€/hour)
Power chain saws	3.5-6
Power slasher	2-4.5
Sprayers/blowers	3.5-4.5
Backpack pump	0.5-1.5
Fire-fighting modules (equipped off-road vehicles)	45-80
Tank trucks	100-150
Earth moving equipment	30-150

3. DAMAGES TO FOREST FUNCTIONS

The damage caused by forest fires to the forest functions is often the most significant component in the total costs. For this reason procedures for estimating this component are of central importance in assessing the total costs of forest fires. Furthermore an accurate estimate of forest function damage usually requires the availability of quite a lot of data and a complex series of estimating procedures that are not needed for the other cost components.

There are three suggested procedures for estimating forest function damage (Figure 2):

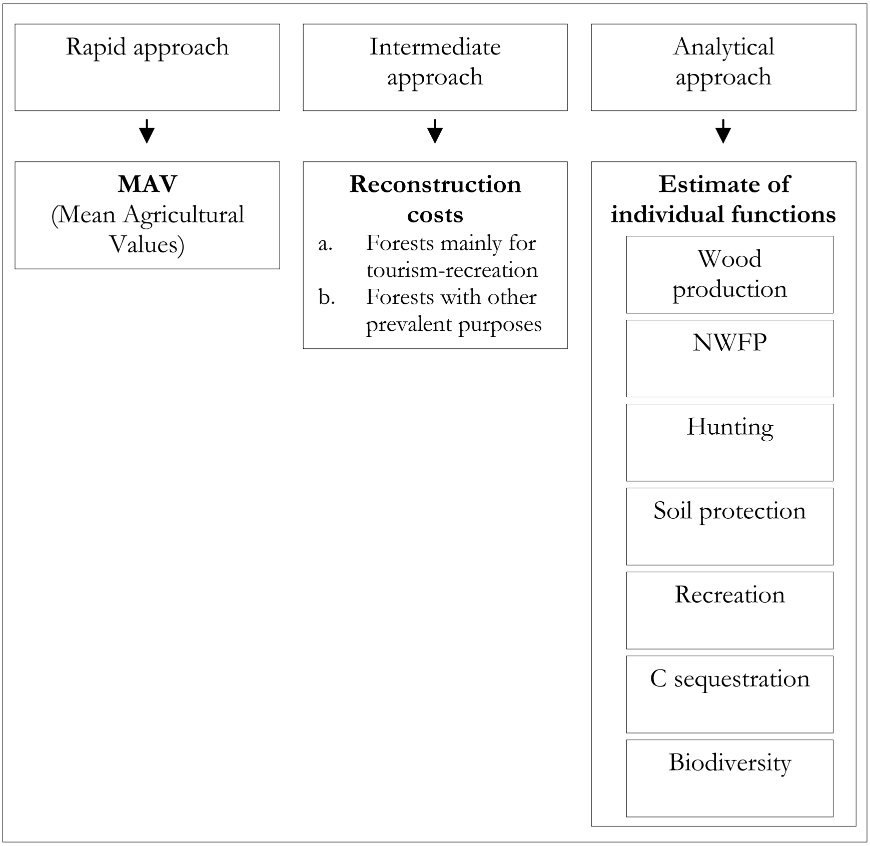

Figure 2 – Procedures for estimating forest function damage.

- a very quick, simple procedure based on the used of land values ("*Valori Agricoli Medi*" or "Mean Agricultural Values") as officially defined in Italy at sub-province level (§ 3.1);
- an analytical procedure based on reconstruction cost criteria differentiated on the basis of forests used mainly for tourism-recreation vs. other forests (§ 3.2);
- an analytical procedure based on separate estimates of the forest's different functions (§ 3.3).

3.1. Rapid approach: using Mean Agricultural Values

For each province in Italy, mainly for estimating land expropriation indemnities, the local offices of the Ministry of Economy and Finance prepare and periodically update tables of Mean Agricultural Values (MAV) per hectare. These values are estimated for all types of agricultural and forest landuse and not only for farmlands *sensu stricto*. The MAV tables also give the mean values of forests (generally broken down into coppices and high forests and with data for specific forest types such as chestnut forests, poplar forests, etc.) and fertile and infertile uncultivated lands.

A rapid estimate of forest function damage can be made on the basis of the following procedure:

$$FD_{MAV} = (MAV_{for} - MAV_{ul}) * area * DL$$

where:
FD_{MAV} = forests functions damage (€); MAV_{for} = Mean Agricultural Value for the forest type most similar to the damaged one (€/ha); MAV_{ul} = Mean Agricultural Value for uncultivated lands (€/ha); *area* = area burned by the fire (ha); *DL* = level of damage caused by the fire.

One problem that may arise in the application of this procedure is the selection of the correct MAV_{ul} value. When using the MAV tables, reference must be made to lowest values that correctly reflect the value of the bare ground. In general these are the *MAVs* for uncultivated land, infertile land and pastures.

The burned forest area (*area*) is a variable that must be accurately surveyed, possibly in the field by GPS instruments or by orthocorrected remotely sensed images.

The level of damage (*DL*), expressed by a coefficient between 0 and 1, is a coefficient that has a high impact on the final outcome of the estimate; here the damage level does not correspond to individual tree mortality, that varies highly in relation to different, specific conditions (tree species, season, vegetative state): instead, such a coefficient derives from an overall rapid assessment of the biophysical damage by the field procedure described in the Appendix.

3.2. INTERMEDIATE APPROACH: RECONSTRUCTION COSTS

A conventional approach for an analytical estimate of forest function damage could be based on reconstruction (restoration) costs.

The evaluation criterion is based on the assumption that an asset is worth at least what it costs originally. Thus, as in the case of the rapid approach (§ 3.1), the reconstruction cost criterion could lead to underestimations of the value of the damaged asset. In fact, the reconstruction cost criterion does not explicitly take into consideration the benefits (with special reference to the non-commercial products and services) that can motivate any given forest owner to manage a forest. Indeed, it is quite logical to hypothesize that if the value of the asset is only linked to its cost and not to the total benefits (that should exceed the costs), no rational operator would even accept the responsibility for investing in the sector. However, the approach is relatively simple; the procedure is based on the following formula:

$$FD_{RC} = RC * area * DL$$

where:
FD_{RC} = forest function damage (€); RC = reconstruction cost (€/ha);
area = area burned by the fire (ha); DL = level of damage caused by the fire.

For the assessment of the area and of the level of damage see § 3.1.

The problem in applying the formula is related to the use of a correct reconstruction cost. There are two considerations in this regard: the first refers to the main function of the damaged forest, the second to the forest age.

Regarding the main function of the damaged forest, it is useful to distinguish between two macro-types, characterized by two different sets of reconstruction costs:

3.2.1. for *forests* used primarily *for recreation* the most logical reconstruction cost refers to ornamental trees; the reference costs thus refer to operations in urban park type areas;

3.2.2. for *other forests* the reference is to conventional forest techniques, based on the use of planting stock from forestry nurseries, with bare roots or in containers.

For *areas of considerable nature conservation value* restoration methods and hence costs can be derived from a combination of these two approaches. In these areas, in fact, it may be necessary to replant both big trees in some areas and seedlings in others. Other complementary actions such as planting shrubs and small-scale engineering works (seeding, drainage works, fencing, etc.) could be also considered.

As to the age of the forest, the estimate cannot ignore the difference, for example, between a 10 year-old stand burned by fire as opposed to a 90 year-old forest. Although the reconstruction costs may be similar, it is obvious that the forest function damage is much greater in the latter case. In other words, we must assess not only the reconstruction cost *per se*, but also the "cost" related to the period needed to the forest to reach an age that allows it to fulfil functions similar to those of the forest before the fire. For this reason the per hectare cost of reconstruction must be estimated as follows:

$$RC = PC * (1 + r)^n$$

where:
RC = reconstruction cost (€/ha); PC = planting cost (€/ha); r = discount rate; n = number of years needed for reconstruction.

In other words, the planting cost (PC), estimated by one of the above two approaches 3.2.1 and 3.2.2, must be accumulated for a adequate number of years (n), using an appropriate discount rate (r).

In light of these considerations the proposed procedure, with the two methods of estimating planting costs, can be summarized as follows:

$$FD_{RC} = PC * (1 + r)^n * area * DL$$

In Italy standard planting costs (PC) for recreational forests (§ 3.2.1) can result in very broad range, roughly from 5,000 to 50,000 €/ha. In the other cases (§ 3.2.2) we can refer to the standard costs for reforestation programs financed under Rural Development Plans, that are 2-4,000 €/ha.

The number of years (n) can be estimated by referring to the age of the burned forest and the type of planting material used (a lower n for 3.2.1 and higher for 3.2.2, for forests of the same age).

In most cases the discount rate (*r*) can be assumed to be between 2% and 5%, with higher values for *r* in cases of more productive forests on fertile soil which can yield greater financial profits. A standard discount rate of 3% is often suggested in Italy for environmental accounting.

3.3. ANALYTICAL APPROACH: ESTIMATE OF THE SINGLE FUNCTIONS

The analytical approach based on the single economic evaluation of different forest functions is the most articulated and complex. The proposed method is based on the use of different methodological approaches for valuating seven products or services (Figure 3):

- fuelwood and industrial wood;
- non-wood forest products;
- tourism-recreation;
- hunting;
- hydro-geological protection;
- protection against climate change (CO_2 emissions);
- nature conservation value.

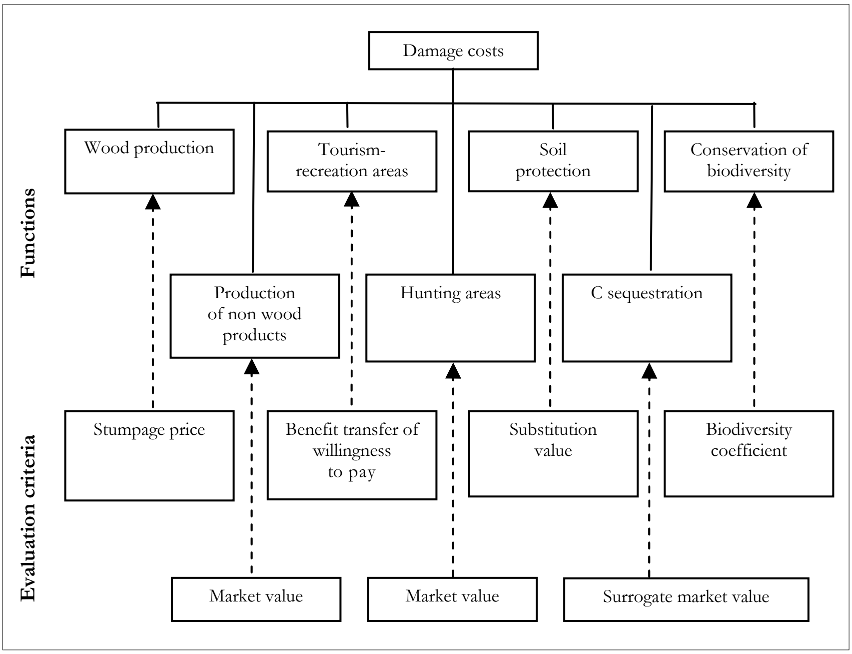

Figure 3 – Functions and criteria for the analytical estimate of forest fire damage.

The total value of the forest function damage is the sum of the appropriate functions for each case at hand. Indeed, the identification of the seven components of the damage does not mean that they are all and always involved in the assessments of the various operating conditions. On the contrary, it is highly unlikely that it will be necessary to assess all the seven components when estimating the economic damage in a specific site.

In general, it is advisable to use the analytical approach with caution in order to avoid the pitfall of overestimates that could lead to unrealistic damage assessment.

3.3.1. Productive function: wood products

The loss of forest biomass and wood-producing capacity is assessed in terms of the market value of the destroyed wood volume. This value is obtained from an estimate of the stumpage value by subtracting the costs of felling and logging from the roundwood market price (i.e. forest road price). In the case of forests that have not reached the maturity age, the commercial value of the destroyed wood does not correctly represent the true roundwood value. For this reason the stumpage value must be evaluated discounting the roundwood market price at maturity by the number of years equal to the difference between the (usual) rotation age and the mean age of the damaged forests. Thus the estimate is made on the basis of the following formula:

$$FD_w = area * Vol * \frac{P_{ro} - C_{fl}}{(1+r)^m}$$

where:
FD_w = forest function damage due to wood-producing loss (€); *area* = area burned by the fire (hectares); *Vol* = volume of commercial wood lost following the fire (m^3/ha); P_{ro} = mean roundwood price at roadside, referred to the usual rotation age (€/m^3); C_{fl} = felling and logging costs (€/m^3); r = discount rate; m = years needed to reach mean rotation age.

For the assessment of the area see § 3.1.

The volume of the wood loss (*Vol*) has to be estimated visually, which is very difficult and uncertain, or better measured by analytical surveys. When estimating *Vol* it is important to remember that two conditions may arise:

- the forest damaged by fire is of an age equal or close to commercial maturity estimated on the basis of the mean rotation of other forests

in the area: in this case (which is the more simple) the volume of wood loss is that assessed on the damaged area;
- the forest damaged by fire is younger than commercial maturity: in this case, starting from an evaluation of the damaged trees, we must estimate the volume they would have attained once they reached commercial maturity.

Roadside prices (P_{ro}), that may be differentiated by species and timber/fuelwood, are in Italy systematically gathered by forest administrations at provincial level. In the case of coppice forests (other than chestnut forests) reference can be made exclusively to the mean roadside price of fuelwood. For other forests the price of the main assortment can be used as the reference.

The felling and logging costs (C_{fl}) can be estimated in standard form, for example they can be broken down into categories which depend on the value of two variables: the slope and the mean distance from the roadside. Standard felling and logging costs developed for the Italian context are shown in Table 4, based on five site conditions:

- easy access (slope ≤20% and the distance from the roadside ≤300 m), 15 €/m^3 are to be subtracted from the mean roadside price;
- moderate access (slope between 20 and 35% and the distance from the road ≤300 m or between 300 and 2,500 m, but with slope ≤20%), 20 €/m^3 are to be subtracted from the mean roadside price;
- difficult access (slope between 20 and 35% and the distance from the roadside between 300 and 2,500 m), 30 €/m^3 are to be subtracted from the mean roadside price;
- very limited access (slope greater than 35%), 35 €/m^3 are to be subtracted from the mean roadside price;
- if the area is very far from the forest road (>2,500 m), the felling and logging costs become prohibitive and the productive function is omitted.

Table 4 – Standard felling and logging costs (€/m^3) in Italy.

Distance from the landing (m)	Slope		
	≤20%	20-35%	>35%
≤300	15	20	35
300-2,500	20	30	
>2,500	no productive function		

Finally, the years (*m*) needed to attain the technically suitable age for wood utilization are a variable that can be estimated at sight by the surveyor. In Italy this variable does not have strong impact on the estimate since under current market conditions the price of fuelwood (which is generally obtainable with relatively short rotations) is very similar to that of sawlogs, so a young forest can be characterized by unit wood prices similar to those of adult forests in similar environmental conditions.

3.3.2. Productive function: non-wood forest products

With regard to the assessment of the economic damage deriving from the reduced availability of non-wood forest products (mushrooms, truffles, aromatic and medicinal herbs, etc.) we base the evaluation on the criteria of the loss of income from the sale of the goods. Since the effects of forest fires are extended over time, the damage must be estimated as the initial accumulation of the yearly damages on the basis of the following formula:

$$FD_{NWFP} = area_{NWFP} * R_{NWFP} * \frac{(1+r)^p - 1}{r*(1+r)^p}$$

where:
FD_{NWFP} = forest function damage from the loss of non-wood forest products (€); $area_{NWFP}$ = area that produces non-wood products burned by the fire (ha); R_{NWFP} = mean annual revenues from non-wood forest products (€/ha); r = discount rate; p = years of lost harvests of non-wood products following the fire.

The area burned by the fire ($area_{NWFP}$) refers to the areas that will temporarily lose its capacity to produce non-wood products. According to stand composition and the site's conditions, $area_{NWFP}$ could be the total area burned by the fire (*area*), part of it, or in some cases, even equal to zero.

The mean annual income from non-wood products (R_{NWFP}) can be estimated by two different methods.

The first, which will presumably be more widely used in Italy, is based on the income from the sale of annual, monthly, weekly or daily collection permits. Obviously, by referring to the sale of harvesting rights, we probably underestimate the damage since this method does not take into account the total real harvest (few, mainly local, users do not pay harvesting fees). Furthermore, the payment of the permit is independent from the quantity actually harvested and, in theory, is always less or equal than the maximum set by law. Thus, this variable refers more to the willingness to pay for a product/service that often has a high tourism-recreational value than the market value of the harvested products.

For the mean annual income from non-wood products (R_{NWFP}) we must also refer to the various local situations. For example: for the mushroom harvest in the Veneto region, a mean annual value of 9.8 €/ha was estimated for the provinces with the highest productivity (Belluno, Treviso) and of 0.3 and 0.5 €/ha for those that produce less (Rovigo and Venice, respectively). On the national level in Italy, CROITORU (2007) estimated a mean annual harvest rate in mushroom producing forests of 3 kg/ha. This was confirmed by BARTOLOZZI (1988) who, in a detailed study of Tuscany, estimated a mean annual rate of 3.1-4.2 kg/ha. In an area that can be taken as a reference for outstanding production and harvests (Borgotaro in the province of Parma) GIOVANNETTI *et al.* (1998) estimated annual output of up to 15-20 kg/ha.

The second method refers to the market value of cultivated products such as chestnuts, hazelnuts, cork, etc. For example in the rare case of fires in chestnut forests, the estimate is made by referring to the market prices of the chestnuts lost output taking into account the age of the forest and a suitable reconstruction period needed to return to ordinary production levels. This category can also include damages related to the loss of grazing function due to the fire.

The years of lost harvests of non-wood products following the fire (p) can be assumed as 10, similarly to what we often assume in Italy for hunting (§ 3.3.4).

3.3.3. Tourism-recreational function

The tourism-recreational function is estimated by a procedure that refers to the number of visits which, following a fire, are no longer made. In particular, two variables are estimated: the total number of visits per area unit and the mean value of each visit.

The recommended procedure does not include an assumption on the area since it is easier to estimate the number of visitors in general terms for the entire area burned by the fire than for area unit.

Activities that will be considered are those related to informal recreation (camping, walks, picnics, etc.), sports (hiking, mountain biking, orienteering, cross-country skiing, etc.) or more specifically nature-based recreation (bird watching, environmental education, etc.) while in order to avoid double assessments the areas used mainly for harvesting non-wood forest products and hunting are not considered since they are the subject of separate assessments.

For tourism and recreation, too, since the fire's effects extend over time, the damage will be estimated as an initial accumulation of a few years loss of the function. The following formula is proposed for this purpose:

$$FD_{rec} = V_{rec} * N_{rec} * \frac{(1+r)^g - 1}{r * (1+r)^g}$$

where:
FD_{rec} = forest function damage from loss of tourism-recreational activities (€); V_{rec} = mean value of one visit (€); N_{rec} = mean number of visitors per year; r = discount rate; g = years of lost tourism-recreational activities following the fire.

According to accessibility, slope and the quality of the forests, the reference area could be the total area burned by the fire or part of it. Where vegetation is particularly thick and impenetrable, the reference area could equal to zero. Furthermore, in some cases the reference area could be bigger than the burnt area when the existence of a section damaged by the fire leads to the lack of utilization of adjacent areas for tourism-recreational purposes.

The value of the single visit (V_{rec}) can be estimated by using a benefit transfer approach, that is by using the results of estimates of tourism-recreational value done with approaches such as the Contingent Valuation, the Travel Costs, or the Hedonic Pricing methods in areas with comparable conditions.

In Italy, on the basis of more than 50 surveys on forest recreational benefits, it is possible to assume that, excluding extreme and anomalous data, the value of a single, one-day visit falls between 3 and 10 €. In order to support the selection of a reliable value based on a short-cut procedure, reference can be made to Table 5.

The number of annual visits (N_{rec}) can be estimated with a reasonable approximation by using the values of proxy indicators related to tourism-recreational activities in the study area (number of parking permits sold, data on local vehicular traffic, data on food and lodging services, etc.), and comparing the values before and after the fire.

The duration of the period of lost recreational function following the fire (*g*) is a variable with a wide range. The number of years will refer to the time needed to restore a recreational-tourism function similar to that of the forest before the fire. Considerable care must be taken if an high number of years is selected since the decision can have a significant impact on the total estimated damage.

Table 5 – Criteria for choosing reference values for estimating recreational services.

Value of a day visit	Purpose of the visit	Social class of visitors	Frequency by individual visitor	Visitor provenance	Site conditions	Accessibility
3 €	Informal recreation; crossing area	Low income level, very young or very old, unemployed or retired	High number of visitors per year	Mainly local	Sloping areas, very dense with much undergrowth, closed landscape	Difficult, unmarked trails with natural obstacles
↑ ↓						
10 €	Organized sports activities; camping, areas for overnight and longer stays	High income level, intermediate age group, employed	Occasional visits	Mainly from long distances	Flat areas, low density forests with clearings and ecotones, open landscape	Easy, with nearby parking facilities

3.3.4. Hunting

In order to estimate the damage related to the decreased potential for hunting we use criteria similar to those given for non-wood products: we evaluate willingness to pay for hunting with reference to the area originally used for this activity.

In this case too, as for non-wood products, the forest function damage extends over time and this must be taken into account through an initial accumulation of yearly income loss following the fire. Thus, the proposed formula is:

$$FD_{hun} = area_{hun} * R_{hun} * \frac{(1+r)^v - 1}{r * (1+r)^v}$$

where:
FD_{hun} = forest function damage from decreased hunting (€); $area_{hun}$ = area used for hunting burned by the fire (ha); R_{hun} = mean annual revenue from hunting (€/ha); r = discount rate; v = years of lost hunting activity following the fire.

$Area_{hun}$ is the extent of the area where the possibility of hunting is temporarily lost. As for non-wood products, according to the composition and conditions of the site, $area_{hun}$ can be identified with the total area burned by the fire (*area*), with part of it, or in some cases, it can even equal to zero.

For the estimate of the mean revenue from hunting (R_{hun}) we suggest referring to the hunters' real payments on the basis of the data on licensed hunters in the area and the annual cost of hunting licenses, thus estimating the mean unit value of the area where hunting is permitted.

As a reference value in Italy, in a study conducted in the Veneto region, a mean annual value of 89 €/ha was estimated for hunting areas; the extreme values on a provincial scale ranged from 38 to 120 €/ha (for the provinces of Rovigo and Vicenza, respectively).

With regard to the variable v, that is the number of hunting years lost following the fire, Italian Law no. 353/2000 concerning forest fires calls for prohibiting hunting for a period of ten years in forests damaged by fire.

The above estimating procedures can also be used to assess damage related to loss of grazing, obviously when conducted in full compliance with forest regulations and local rules. In this case, the mean income will be estimated on the basis of the annual rental fee for the land or other types of contractual arrangements between land owners and grazers.

3.3.5. Soil protection function

In order to estimate the value of the forest's protective function, we suggest an approach based on the criterion of replacement costs, using the lump sum costs for revegetation (i.e. grassland regeneration) of the area burned by the fire. In particular, revegetation costs comprise two components: the *una tantum* costs of the operation and the costs of area maintenance which we suppose must be done annually for a number of years in order to recover the previous protective capacities of the area that has been burned. Hence, the following formula can be used:

$$FD_{prot} = area_{prot} * \left(C_{rev} + C_{ann} * \frac{(1+r)^i - 1}{r * (1+r)^i} \right)$$

where:
FD_{prot} = forest function damage from the decreased protection (€); $area_{prot}$ = area with protective functions burned by the fire (ha); C_{rev} = cost of revegetation (€/ha); C_{ann} = mean annual maintenance costs of the revegetation area (€/ha); r = discount rate; i = years needed to manage the revegetation area.

The area with water cycle regulation and soil protection functions burned by the fire ($area_{prot}$) must be considered with caution: the use of the replacement cost criterion involves reference to intensive engineering works that are highly effective but also particularly expensive and are only justified when there is significant deterioration of the soil stabilizing and water cycle regulation services. To avoid overestimates, this approach must be restricted to areas with steep slopes and which have become highly unstable specifically after the fire and not to those which play a minor protective role.

In order to have an univocal delineation of $area_{prot}$ threshold values for mean slopes should be defined, below which the economic damage related to the soil erosion can be assumed to be not significant (in Italy we defined a minimum threshold of a 40% mean slope). We can also consider variable mean slope thresholds to correspond with different types of operations whose costs rise in proportion to the increase in slope. For example, for the Italian context, the following slope thresholds have been defined:

- <40%: no significant damage;
- 40-70%: damage valued in relation to the need for extensive interventions (consolidation of rocks, grass seeding, etc.);
- >70%: damage valued in relation to intensive interventions (stepping, planting cuttings, drainage, stone supporting walls, protecting the ground with nets, etc.).

When the burn forest is on a steep areas located immediately above main roads it is possible to refer the engineering works needed to stabilize the soil over the road.

The mean cost of revegetation (C_{rev}) can be estimated in relation to grass seeding techniques. The prices of seeding vary in relation to the equipment used, which in turn is related to the size and location of the area. For localized operations in Italy we assumed a cost of 12,000 €/ha, and for extensive operations using helicopters we defined a mean cost of 3,000 €/ha.

The annual maintenance costs for the replanted area (C_{ann}) and the number of years that maintenance is required (i) refer to the grassland care and management operations (cutting, reseeding and thickening, etc.) which are needed to stabilize the new green cover replacing the one destroyed by the fire. In some contexts, when the only intervention needed is that one carried just after the fire, these variables can be assumed equal to zero.

3.3.6. Carbon dioxide sequestration function

Carbon dioxide emissions due to the combustion of wood biomass, with a consequent increase in the concentrations of greenhouse gases in the atmosphere, involve a cost that can be estimated by referring, as a surrogate market for carbon credit, to market prices of carbon quota (see the *Emission Trading Scheme* of the European Union). These prices are transparent following the implementation of the Kyoto Protocol, the creation of a market for Carbon quota related to the "flexible mechanisms" (such as the Clean Development Mechanism and the Joint Implementation), the voluntary creation of a series of compensatory actions by local authorities, businesses and even individual citizens.

The proposed procedure is based on the use of the data relative to the area burned by the fire, the destroyed wood stock, the price of a ton of carbon and transformation coefficients:

$$FD_C = area * Vol_b * BEF * 0.5 * PR_C$$

where:
FD_C = forest function damage from carbon emitted into the atmosphere (€); *area* = forest area burned by the fire (ha); Vol_b = volume of the wood mass burned by the fire (m^3/ha); *BEF* = biomass expansion factor (coefficient of transformation of the wood volume, expressed in m^3, into above-ground tree biomass, expressed in t of dry

matter); 0.5 = coefficient of transformation of biomass into carbon; PR_C = price of one ton of carbon (€/t).

For the quantification of the area burned by the fire (*area*) see section § 3.1. The volume of the burned wood mass (Vol_b) can be obtained from a visual estimate, which however is very difficult and uncertain, or better measured by analytical surveys. As an approximate rule Vol_b will be equal to the volume estimated for the quantification of the damage deriving from the loss of commercial timber.

The data concerning the destroyed stock generally refer to the dendrometric wood mass and therefore must be multiplied by an expansion factor (*BEF*) in order to estimate the total loss of biomass. Table 6 shows the BEFs that can be used in estimates for forest vegetation types in Italy. The BEFs shown refer only to above-ground biomass since it is very rare for a fire to lead to the carbonization of the underground C content, and even in those cases the estimate of the destroyed underground mass is usually hazardous.

The price per ton of carbon on the international market (PR_C) can be updated by analyzing the web sites of some organisation that monitor C quota transactions (http://www.pointcarbon.com/, http://carbonfinance.org/). It is advisable to refer to quotations regarding operations in the fields of agricultural and forest land management since they refer to temporary carbon sequestration from the atmosphere (for this reason the value of the quotas are, *ceteris paribus*, lower).

Table 6 – Approximate BEF values for forest vegetation classes as per Table A.1 (see Appendix).

Class code	BEF (t/m^3)
A	0.80
B	0.95
C	0.60
D	0.70
E	0.80
F	0.90
G	1.00
H	0.90
I	0.60

3.3.7. Biodiversity protection function

Of all the factors under consideration, the biodiversity conservation role of forests, that is the value attributed to the biodiversity of its components, is the most difficult to evaluate. A simplified estimation procedure has been defined for Italy referring to article 11 of State Law no. 353/2000 which states that, when a fire damages a protected area, the total value of the forest function damage as estimated using conventional methods has to be increased by fifty percent. Starting from this formal decision made by the policy makers, we have assumed a similar and consistent, but more elaborate criteria for evaluating the biodiversity function: the procedure is based on the application of a multiplier coefficient to the sum of the six functions described above. This method, however, does have a shortcoming: quite frequently, in areas of high environmental value the financial losses from lost wood production, non-wood forest products or hunting are limited (in the case of totally protected areas these functions are equivalent to zero) and the multiplication coefficient has to be applied to practically insignificant values. We could arrive at the situation - far from empirical evidence - that the value of protecting the biodiversity of semi-natural forests with high commercial production potential is greater than that of fully protected natural forests. To overcome this problem the multiplier coefficient refers to the reconstruction value, so that the formula (similarly to what we have defined in section § 3.2) would be the following:

$$FD_{bio} = 0.5 * area * DL * PC * (1+r)^n$$

where:
FD_{bio} = forest function damage related to biodiversity loss (€); *area* = area burned by the fire (ha); *DL* = damage level of the fire; *PC* = planting costs (€/ha); *r* = discount rate; *n* = number of years needed for reconstruction.

Albeit this formula is based on a reasonable assumption and a coherent procedure, it strongly simplifies the evaluation by not discriminating between different conditions of site biodiversity, even if makes it possible to give adequate weight to the forest age parameter that is correlated to the level of biodiversity. For a more appropriate weighting of the different biodiversity conservation functions of the damaged areas we propose a rating scale for the multiplier that goes from nearly zero to the highest values of biodiversity. On such a basis the proposed formula for estimating nature conservation value becomes:

$$ED_{bio} = coef_{bio} * area * DL * PC * (1+r)^{n}$$

where:
$coef_{bio}$ = naturalness coefficient (Table 7).

The adjustment coefficient for each type of forest was defined by considering various attributes of the forest in positive correlation with biotic diversity and/or environmental value.

For the estimation of the formula's other variables (*area*, *DL*, *r*, *PC*, *n*) we refer to the foregoing.

Table 7 – Naturalness coefficient ($coef_{bio}$) for estimating the nature conservation values of different types of forests burned by fire in Italy.

Forest type	$coef_{bio}$
Plantations of exotic species	0.1
Monospecific coppices regularly managed (age under 1.5t*)	0.2
Mixed coppices regularly managed (age under 1.5t*)	0.3
Scrub and Mediterranean maquis	0.4
Compound coppices	0.5
Coppices under conversion to high forest **	0.6
Monospecific high forests	0.7
Mixed high forests	0.8
Reforestation in the renaturalisation phase	0.8
Multi-layered mixed high forests and riparian forests	0.9
Old-growth forests	1

(*) t = minimum rotation age set forth by forest regulations
(**) coppices under natural conversion to high forest (age >1.5 of the conventional rotation period) or coppices where silvicultural intervention for the conversion to high forest has been started

4. EXTRAORDINARY EXTERNAL DAMAGES

As in other Countries, according to the provisions of the Italian Civil Laws, any person who causes damages to property shall be responsible for. More specifically, the following must be taken into consideration when calculating the damage:

- the severity of the individual guilt;
- the restoration costs;
- the perpetrator's illicit gain deriving from having damaged environmental assets.

The first item is evaluated by the judiciary who is duly informed by the police authorities and surveyors; the evaluation of the severity of guilt is nothing more than the objective result of the application of the estimation appraisal procedures presented in this document.

The cost of restoration includes the sum of the expenses incurred in fighting the fire and the appraisal of damage to the forest and soil. These items have been here considered with specific reference to the normal conditions of the forest resources, and the functionality of the forest resources from an "insider" and sector-oriented standpoint. However, forest fires (especially those ones of large size) may be associated with external damages of relevant economic impact, especially when taking into consideration the third component of the damage: illicit gain. This can take different forms which are not always easily predictable or calculable: real estate/building speculation, grazing in forests burned by fire, hunting facilitated by the shrinkage of the authorized hunting areas and concentration of wildlife, up to the use of fires to threaten and illegally influence the owners of the forests, immediate families and kin, or the local officials in charge of preventing and fighting forest fires.

No specific guidelines or instructions can be given for how to calculate illicit gain; it must be done on a case by case basis for the type of presumed or real profit that was created. However, external damages fall into three categories (Figure 4):

- property damage (§ 4.1);
- damages related to civil defence operations that were made necessary during or as a result of the fire (§ 4.2);

- damage to human resources, that is temporary or permanent disability and, in extreme cases, loss of life (§ 4.3).

We will briefly consider the estimation methods for these three types of damages. In all cases we suggest an analytical approach without providing specific appraisal procedures but only general methodological guidelines.

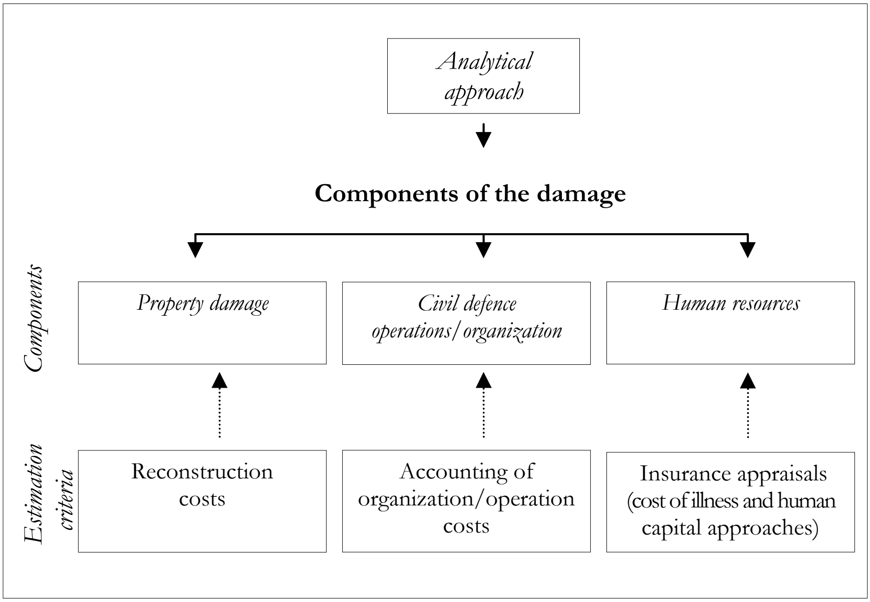

Figure 4 – Procedures for estimating extraordinary damages.

4.1. PROPERTY DAMAGE

Even moderate fires causing limited environmental damage can involve significant costs related to the partial or total destruction of property. "Property" includes both public and private assets of different types:

- civil infrastructures, such as power lines, roads, parking and rest areas, signage, etc.;
- homes and rural structures and buildings (shelters, storage facilities, sheds, fencing, etc.);
- farm crops (orchards, vineyards, etc.) and animals (other than wildlife);

- monuments and the historical cultural heritage (shrines, tabernacles, capitals, etc.);
- environmental heritage and assets (monumental and historical trees, etc.).

When dealing with property damage, the appraisal method is generally based on the cost of reconstructing the damaged parts, which is reduced as necessary by the use of an appropriate ageing coefficient.

If the damage affects a portion of a larger asset, but comprises its overall value, it is appropriate to make two separate appraisals of the asset (with and without damage) and obtaining the value of the damage from the difference between the results of the two appraisals.

In the case of monuments and the historical, cultural and environmental heritage the criteria of cost of reconstruction may not always be appropriate, and more complex methods will have to be used such as the Contingent Valuation, the Hedonic Price and the Travel Costs methods. In these cases the complexity of the appraisal methods requires a specific contribution from professionals.

4.2. Damages related to civil defence operations

This category includes the organizational expenses related to civil defence operations in cases of severe events, even of local nature, but in densely populated areas: evacuation of residents and tourists, closing roads, suspending services, interrupting businesses (hotels, food services, sports, farming, etc.), implementation of extraordinary services to provide support and information to the residents, etc.

The costs of such operations are difficult to standardize and the appraisal must, therefore, be based on costs and loss of income verifiable through the accounting records of the parties involved in the operations.

Only in some cases, for services similar to those provided under ordinary conditions, can the appraisal be based on short-cut methods such as standard costs or prices lists (e.g., transportation of persons and things).

4.3. Personal injuries

Accidents leading to temporary or permanent disability or loss of life related to extinguishing a fire or caused by the fire itself are not uncommon occurrences.

In the first case the accident victim generally has insurance coverage and the appraisal can be taken from the one made by the insurance company in determining the compensation.

In the second case, even when the victim has no insurance coverage, the procedures followed in estimating the compensation for insured persons (cost of illness and human capital approaches) provide a consolidated reference in estimation practice.

5. OPERATIONAL ASPECTS FOR ORGANIZING THE ASSESSMENT

The proposed estimation procedures differ as to data-information requirements and time to be spent for collecting and processing the data. The choice of the most appropriate procedure is left to the forest administration. We can, however, provide some general criteria to use in making that choice. It is a matter of finding a compromise between:

- reducing the information requirements for a fair economic evaluation to the minimum in order to contain the costs of the evaluation itself;
- correctness and reliability of the evaluation.

This second requirement is also related to the fact that the estimate may also be required in legal action for compensation and, as such, must be based on robust methodology and reliable data.

Table 8 shows a grid for identifying procedures for estimating the costs of operations and appraising the damage in relation to the area burned by fire, and identifying the type of damage. These are rough approximations: the decision to use a more or less simplified procedure cannot be made on the basis of rigorous quantitative criteria, but rather it must be based on considerations on a case by case basis.

It is important to stress that if the guidelines in Table 8 are used, on the basis of forest fire data over the past few years in Italy, approximately 80% of the events and 12% of the area burned by fire could be estimated using the simpler procedures.

Table 8 – Guidelines for the selection of methods for estimating economic damage and levels of administrative responsibility for the appraisal in Italy.

<table>
<tr><th rowspan="2">Burned area (ha)</th><th colspan="2">Recommended method (number of the chapter of this document)</th><th rowspan="2">Forest administrative level responsible for the appraisal</th></tr>
<tr><th>Very limited public functions, reduced production values</th><th>Public functions; relevant production values</th></tr>
<tr><td>>5</td><td>§ 2.2+3.2</td><td>§ 2.3+3.3</td><td>Region</td></tr>
<tr><td>1-5</td><td rowspan="2">§ 2.1+3.1</td><td>§ 2.2+3.2</td><td>Province</td></tr>
<tr><td><1</td><td>§ 2.1+3.1</td><td>Municipality</td></tr>
</table>

Table 9 – Examples of application of the proposed appraisal procedures.

Type of area burned	Cost components		
	Cost of extinguishing the fire	Forest function damages	Extraordinary external damages
Very limited area of coppice mainly for productive purposes	Rapid approach (standard costs)	Rapid Approach (MAV)	Not considered*
Black locust forest in intensively farmed area	Rapid approach (standard costs)	Rapid approach (MAV)	Not considered*
Limited area of a fast growing plantation	Rapid approach (standard costs)	Intermediate approach (reconstruction cost) or analytical approach with evaluation of only the productive function	Not considered*
Limited area of Mediterranean maquis with mainly shrubs	Rapid approach (standard costs)	Intermediate approach (reconstruction cost) or analytical approach with evaluation of only the productive function	Not considered*
Turkey oak highforest in mountain area	Intermediate approach (price lists)	Analytical approach (with possible verification of data using intermediate approach)	Not considered*
Extensive coastal pine forest with relevant soil protection and landscape enhancement functions	Intermediate approach (price lists) or analytical approach if the operation was large-scale and required special methods to put out the fire	Analytical approach (with possible verification of data using intermediate approach)	Considered
Extensive mixed peri-urban forest for multiple uses (recreation, landscape, etc.)	Analytical approach (accounting)	Analytical approach (with possible verification of data using intermediate approach)	Considered

(*) unless there were specific and significant damages to persons or infrastructures

For further guidance in selecting the estimation procedure, Table 9 shows some examples of concrete applications.

We must emphasize that, as a rule when making complex appraisals of large and highly valuable property, it is possible to use more than one procedure for estimating the same cost component in order to verify and consolidate an appraisal.

CONCLUSIONS

The general awareness, that has matured in recent years, of the need and utility of taking proper account of the total economic value of the environmental resources opens new scenarios for the assessment of the effects of forest fires. Environmental accounting of forest fire damages is a basic requirement for investment planning to limit soil degradation and biodiversity deterioration. This is a vital problem for a country such as Italy where the forest offers not only wood and non-wood products, but also a large set of public services: a unique reserve of biodiversity, incomparable and priceless landscapes, strictly connected with the history and culture.

The research paper offers some guidelines for the evaluation of some of the forest's roles and functions. The methodological approach only partly fulfils the need for a monetary assessment of the forest system's total value. It is, however, an operational tool defined by multidisciplinary approach aimed at improving the economic assessment of damages caused by forest fires.

Obviously, correct practice in systematic appraisals of highly diversified types of forest fires should be based on a continuing improvement of the assessment methodologies. The improvement must come from a critical evaluation of past experiences, a weighting of the relationship between costs and benefits of the estimates, the full use of all modern tools for monitoring the burned area and automatic processing of environmental and socio-economic data which information technology provides.

From this standpoint, the methods proposed in this document lend themselves to further study and research in a hoped-for follow-up to what has been done up to now.

REFERENCES

ARROWOOD J., 2003 – *Living with wildfires: prevention, preparation and recovery*. Bradford Publishing, Denver.

AYLWARD B., 2004 – *Land-use, Hydrological Function and Economic Valuation*. In: Bonnell M., Bruijnzeel L.A. (eds.), Forests-Water-People in the Humid Tropics. Cambridge University Press, Cambridge.

BARBOSA P., SAN-MIGUEL-AJANZ J., CAMIA A., GIMENO M., LIBERTÀ G., SCHMUCK G., 2004 – *Assessment of fire damages in the EU Mediterranean countries during the 2003 forest fire campaign*. Official Publication of the European Commission, S.P.I.04.64, Ispra.

BARTOLOZZI L., 1988 - *Ricerca sui prodotti spontanei del bosco e degli altri ambienti naturali in dieci comuni della Garfagnana*. In: Sorbini M., Bartolozzi L., Della Casa R., Indagine sul ruolo economico dei prodotti secondari spontanei del bosco. Accademia Italiana di Scienze Forestali, Firenze, p. 24-54.

BISHOP D.K., PHILLIPS A.C., 1993 – *Seven steps to market - the development of the market-led approach to countryside conservation and recreation*. Journal of Rural Studies, 9 (4): 315-338.

BLASI C., BOVIO G., CORONA P., MARCHETTI M., MATURANI A. (eds.), 2005 – *Fires and ecosystem complexity. From forest assessment to habitat restoration*. Executive summary. Ministero dell'Ambiente e della Tutela del Territorio, Società Botanica Italiana, Palombi & Partner, Rome.

BOQUIREN, 2004 – *Rewards for Environmental Services in the Philippines Uplands: Constraints and Opportunities for Institutional Reform*. World Agroforestry Centre (ICRAF), Bogor.

CIANCIO O., CORONA P., IOVINO F., MENGUZZATO G., SCOTTI R., 1999 – *Forest management on a natural basis: the fundamentals and case studies*. Journal of Sustainable Forestry, 1/2: 59-72.

CIANCIO O., IOVINO F., NOCENTINI S., 1996 – *A new dimension of the Mediterranean forest for the prevention of forest fires*. In: O. Ciancio (ed.), The forest and man, Accademia Italiana di Scienze Forestali, Florence, p. 269-285.

CORRADO G., 1989 – *Le funzioni del bosco e le valutazioni dei suoi benefici*. In: Bandini M., Guerrieri G., Sediari T., Istituzioni di economia e politica agraria. Edagricole, Bologna, p. 447-455.

CORRADO G., ROSSI A.C., SEDIARI T., 1987 – *Gli aspetti economici della tutela della foresta*. In: Il bosco e l'ambiente. Atti XVII Incontro di Studio Ce.S.E.T. Firenze, p. 387-397.

CROITORU L., 2007 – *How much are Mediterranean forests worth?* Forest Policy and Economics, 9: 536-545.

EMERTON L., BOS E., 2004 – *Value. Counting ecosystems as an economic part of water infrastructure*. IUCN, Gland and Cambridge.

ENGLIN J., LOOMIS J., GONZÁLEZ CABÁN A., 2001 – *The dynamic path of recreational values following a forest fire: a comparative analysis of states in the Intermountain West*. Canadian Journal of Forest Research, 31 (10): 1837-1844.

FLOWERS P.J., SHIKLE P.B., CAIN D.A., MILLS T.J., 1985 – *Timber net value and physical output changes following wildfire in the Northern Rocky Mountains: estimates for specific fire situations*. USDA Forest Service, Pacific Southwest Research Station, Research Paper PSW-179, Albany.

FLOWERS P.J., VAUX H.J., GARDNER P.D., MILLS T.J., 1985 – *Changes in recreation values after fire in the Northern Rocky Mountains*. USDA Forest Service, Pacific Southwest Research Station, Research Note PSW-373, Albany.

GIOVANNETTI G., ZINGARI, P., TERZOLO P., 1998 – *Exploitation of forest productivity through increased mushroom production*. Acta Hort. (ISHS) 457: 127-132.

GRIMM V., WISSEL C., 1997 – *Babel, or ecological stability discussions: an inventory and analysis of terminology and a guide for avoiding confusion*. Oecologia, 109: 323-334.

HUNTER M.L. (ed.), 1999 – *Maintaining biodiversity in forest ecosystems*. Cambridge University Press, Cambridge.

IIED, 2003 – *Valuing Forests: A review of methods and applications in developing countries*. International Institute for Environment and Development, Environmental Economics Programme, London.

JOHNSON E.A., MIYANISHI K. (eds.), 2001 – *Forest fire behaviour and ecological effects*. Academic Press, New York.

JOHNSON N.L., BALTODANO M.E., 2004 – *The economics of community watershed management: some evidence from Nicaragua*. Ecological Economics, 49 (11): 57-71.

MARCHETTI M., PETTENELLA D., 1994 – *La vegetazione e il fuoco: analisi di alcune componenti del rischio e dei costi economici*. Cellulosa e Carta, 45 (3): 17-27.

MARINELLI A., ROMANO D., 1987 – *L'analisi della domanda di ricreazione all'aperto in foresta: aspetti metodologici ed applicativi*. Studi di Economia e di Diritto, 2: 123-153.

MATERO J., SAASTAMOINEN O., 1993 – *Economic evaluation of environmental impacts of forestry on water-based values in Finland.* Proc. Conference of the Scandinavian Society of Forest Economics, Gilleleje.

MERLO M., CROITORU L. (eds.), 2005 – *Valuing Mediterranean forests. Towards total economic value.* CABI, Wallingford.

MICHIELI I., MICHIELI M., 2002 – *Trattato di estimo.* Edagricole, Bologna.

MIRANDA M., PORRAS I.T., MORENO M.L., 2003 – *The social impacts of payments for environmental services in Costa Rica. A quantitative field survey and analysis of the Virilla watershed.* International Institute for Environment and Development, London.

NAUTIYAL J.C., DOAN G.E., 1974 – *Economics of fire control.* Canadian Journal of Forest Research, 4 (1): 82-90.

PAGIOLA S., RITTER K. VON, BISHOP J., 2004 – *Assessing the economic value of ecosystem conservation.* The World Bank, Environment Department Paper 101, Washington DC.

ROJAS M., AYLWARD B., 2003 – *What are we learning from experiences with markets for environmental services in Costa Rica? A review and critique of the literature.* Environmental Economics Programme, International Institute for Environment and Development, London.

TRABAUD L., 1989 – *Les feux de foréts.* Editions France-Selection, Montpellier, Cedex.

TRAGSO, 2002 – *Valoración económica integral de los sistemas forestales de la Comunidad Valenciana.* Plan general de ordenación forestal de la Comunidad Valenciana. Valencia.

TURNER K., GEORGIOU S., CLARK R., BROUWER R., BURKE J., 2004 – *Economic valuation of water resources in agriculture from the sectoral to a functional perspective of natural resource management.* FAO Water Reports 27, Roma.

VAN NOORDWIJK M., CHANDLER F., TOMICH T.P., 2004 – *An introduction to the Conceptual Basis of RUPES: rewarding upland poor for the environmental services they provide.* ICRAF-Southeast Asia, Bogor.

VAUX H.J., GARDNER P.D., MILLS T.J., 1984 – *Methods for assessing the impact of fire on forest recreation.* USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-79, Albany.

METHOD FOR FOREST FIRE DAMAGE LEVEL ASSESSMENT BASED ON DETECTABLE EFFECTS

PRELIMINARY STEPS

1. Identifying the perimeter and area of the burned land on topographic support.
2. Mapping dominant vegetation according to the classes listed in Table A1; this map may prudently be extended beyond the perimeter drawn in Step 1.
3. Localizing the ignition point in order to identify the area where the fire manifested its acceleration phase.
4. Reconstructing the main direction of advancement of the head of the fire during the acceleration phase and subsequent positions of the front at specific intervals (to be selected on the basis of the total duration of the fire).
5. Reconstructing the direction of the flanks (or secondary fronts for large fires) and subsequent positions of the lateral fronts at specific intervals (to be selected on the basis of the total duration of the fire).
6. Determining the *area burned during the acceleration phase*. It is assumed that 60% of the area within the fire perimeter is burned during 20% of the duration of the fire. This rule may tend towards underestimations: a correction can be made on the basis of information from the personnel who directed or participated in the extinguishing operations.
7. Determining the rate of spread of the *acceleration phase,* even by taking into account the *mean rate of spread* (*ha/hour = area/(time of fire start-time of fire end)*). This information is supplementary; it can only be obtained from eyewitness information about the position of the fire front during the initial phase and in the transition phase between acceleration and the *quasi*-steady state; if this information is obtained it can be used to confirm the position of the acceleration zone.
8. Analysing and locating the fire-fighting operations.
9. Ascertaining gaps and uneven behaviour along the fire path.

If it is possible to obtain information while the fire is burning, steps 4 to 9 must be considered as active surveying phases.

Table A.1 – Forest vegetation classes grouped by fire regime and effects in Italy (A-G classes are intended for forest stands with mean height above 3.5 m).

Class code	Physiognomical characterization
A	Maple-ash forests Hygrophilous riverbank forests Lowland oak high forests Beech high forests Birch high forests
B	European pubescent and Turkey oak high forests Evergreen oak high forests
C	Larch and larch-arolla pine forests Spruce forests Fir forests Mixed fir and spruce forests Mountain Scots pine forests Mountain black pine forests
D	Hilly and flatlands Scots pine forests Calabrian and palebark pine forests and hilly black pine forests Mediterranean pine forests Other conifer forests
E	Beech coppices Chestnut coppices Hardbeam coppices
F	European and pubescent oak coppices Turkey, Italian, Valonia and Macedonian oak coppices European hophornbeam coppices Evergreen oak coppices
G	Mediterranean maquis
H	Mainly broadleaved forest stands with a mean height less than 3.5 m
I	Mainly conifer forest stands with a mean height less than 3.5 m

SURVEY OPERATIONS

The survey phase consists in observing detectable observations of effects of the passage of the fire. Although there may be many signs of evidence only some will be noted. The *maximum* (Hs_{max}) and *minimum* (Hs_{min}) *scorch heights* on trunks have been identified as useful indicators for determining fire behaviour.

The maximum scorch height identifies the probable height of the flame which in turn is correlated to the intensity of the fire front. This indicator gives information about the occurrence and intensity of the fire in all areas with trees, independently of the species, management, methods and silvilcultural treatments. For the purposes of the method, the following formula can be used: $I = 3\ (10h)^2$, where I = fireline intensity (in kW/m); h = maximum scorch height (in m). This allows us to have an idea about the intensity of the flame front/fire front.

We also have to note the *position of the scorch-marks on the trunck*. We begin by identifying the location of the maximum and minimum scorch heights with respect to a fixed reference (e.g. North). The heights of the maximum and minimum scorch are usually located on circular sectors along the trunk.

If, on a sufficient number of trees, we find that the vertical lines drawn with respect to the points of maximum and minimum scorch heights on the trunks tend to be parallel, we can obtain a reliable indication of the direction of the fire's path. A constant alignment of many lines drawn as described above makes it possible to determine the general direction of the advancing front. The minimum scorch height indicates from where the fire arrived, the maximum shows the height from which it moved on.

The relationship Hs_{min}/Hs_{max} varies between 0 and 1 as a function of the intensity of the fire and the dominant vegetation. Its value become lower as the difference between the two scorch heights increases. However, irrespectively of the value of Hs_{min}/Hs_{max} (especially moving away from 1) it is valid as a direction indicator.

The combination of the direction and intensity provides information about the spread and makes it possible to extrapolate information for a given area. In fact, for a clearly defined direction favoured by slope or wind and at a high fire intensity (over 1500 kW/m) we can assume that we will have to look for effects over a distance of 100 m in the direction of fire advancement.

LOCALIZATION

The analysis should begin with a survey in the fire acceleration zone. The visual examinations and evaluations of the fire occurrence in this area will probably be the easiest. In fact, this is the area of highest intensity.

Following the quick survey, we proceed with a preliminary confirmation of the acceleration zone. After we identify it, we investigate other zones where the front spread constantly and where it diminished. In these areas the intensity is usually decreasing and fire-fighting is more successful. For this reason the effects of the fire are less easily identifiable. Therefore, greater surveying accuracy is required.

QUICK SURVEYS IN THE ACCELERATION ZONE

On the basis of item 6 of the preliminary steps, Hs_{max} and Hs_{min} in the acceleration zone must be determined and pinpointed to ascertain the intensity and direction of the fire's advance.

QUICK SURVEY IN THE QUASI-STEADY SPREAD ZONE

On the basis of items 5 and 8 of the preliminary steps, we can estimate the perimeter at the moment the fire-fighters go into action and assess their effects. If eyewitness information is available we investigate the transitions between the acceleration, constant spread and slowdown phases. In all the areas characterized by these phases we note the same variables in a similar manner; fewer surveys are needed in these areas with respect to the acceleration zone.

VERIFICATION OF PREVIOUS FIRES

Previous fires have to be verified. We must ascertain that there were no fire fronts that crossed the same area for a period long enough to have permitted complete reconstruction of the forest. The hypothesized reconstitution must have taken place during the period between the first event and the second more recent fire.

A previous fire can be confirmed from the information obtained from two (or more) reports. If there is the suspicion that a previous fire occurred we proceed with the appropriate verification. Evidence can be observed quite often during a survey: it is revealed by the signs of uneven-aged thermal trauma; it is easier to identify these signs in the acceleration zone if they are caused by intense fires that occurred within a sufficient time interval. Likewise, the possibility of identifying previous fires diminishes with the decrease in intensity and with the shortening of the interval between two fires. However, the probability of identifying previous fires decreases with the increased intensity of the first event and shortening of the time between the two fires. Previous fires is certain if we find even-aged sprouts following a fire and uneven-aged scorching caused by the two events.

Having noted the evidence of a previous fire we can distinguish the two events (theoretically even more than two) that occurred in the same area at different times. However, we only investigate the more recent of the two, but when there is evidence of damage from previous events, further investigation is needed.

UNBURNED AREAS

Within the perimeter of the fire there could be areas that were not burned. They are revealed by the absence of traces and for the better vegetative state which is more obvious when the fire was recent. If unburned areas are found, they must be identified because they can provide useful information about the dynamics of the fire front.

DATA PROCESSING

1. Determination of the Hs_{min}/Hs_{max} ratio provides information about the intensity and the spread of the fire front.
2. Determination of the intensity of the acceleration zone.
3. Determination of the intensity of the *quasi*-steady spread zone.

Intensity is expressed in classes. The level of damage *(DL)* is given for each forest vegetation and intensity classes, as shown in Table A.2.

Table A.2 – Level of damage broken down by intensity and forest vegetation classes.

Forest vegetation classes (see Table A.1)	Scorch height (m)				
	<1	1-2.5	2.5-3.5	3.5-4.5	>4.5
	Intensity (kW/m)				
	<350	350-1,700	1,701-3,500	3,501-7,000	>7,000
A	0.10	0.15	0.30	0.60	
B	0.08	0.20	0.30	0.80	0.90
C	0.10	0.25	0.50	0.80	0.90
D	0.08	0.30	0.55	0.85	0.95
E	0.05	0.15	0.40	0.65	
F	0.05	0.20	0.35	0.60	0.95
G	0.10	0.30	0.60	0.80	0.95
H	0.30	0.70	0.80	0.90	1.00
I	0.25	0.40	0.70		

FINAL CONSIDERATIONS

Survey efforts will increase as the ratio Hs_{min}/Hs_{max} approaches 1. The farther the linear intensity goes below 400 kW/m the fewer survey efforts will be needed, as the damage decreases progressively. We estimate that a relévee should be made, on average, at least every 2,500 m^2.

In general, we maintain that the survey campaign:

- should initiate from the presumed starting point of the fire;
- should be conducted walking along the contour lines;
- should be more detailed in the acceleration zones;
- should begin from the presumed starting point towards the head of the fire and only then from the same starting point towards the fire tail.

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