

# MANAGEMENT OF AGROFORESTRY SYSTEMS

Ecological, social and economic approaches



Esther Fernández-Núñez

Marina Castro

**Editors**

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# **Chapter VIII**

## **Economic impact of forest fires: methodologies for assessing losses**

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Intensive program Management of agroforestry systems: ecological, social and economic approaches

## **ABSTRACT**

The forest industry is a strategic sector for countries' national development, particularly for rural areas, given its economic, social and environmental functions. Fires are among the biggest threats to Portuguese forests. The main objective of this study is to contribute to the understanding of the economic impact of forest fires and its importance for an efficient management of costs. Thus, we discuss optimal level of fire protection and the economic and social impacts of fire, and present some methodologies for assessing losses caused by forest fires. Social and economic impacts of fires can be extensive, long-lasting and difficult to identify and assess. We address the assessment of losses by forest fire on tradable and non-tradable services and goods. The concept of present value is used to assess the losses on tradable goods, such as wood and other forest products; including recreational services and equipment and infrastructures, and the concept of economic value of environmental resources is used to assess the losses on non-tradable goods. Several examples are presented of the assessment of the economic impact of forest fires using market prices, hedonic prices, travel costs, transference of benefits and contingent valuation methods to value losses on non-tradable assets and, finally, a practical work exercise assessing the costs of a forest fire is illustrated.

**Keywords:** forest fires; economic impact; losses in tradable and non-tradable goods.

## **INTRODUCTION**

Worldwide the forest industry is a strategic sector for countries' national development, mainly for rural areas. The Portuguese forest, in particular, occupies 38% of the national territory with 3,450 million hectares, the 12<sup>th</sup> largest forest area in the European Union, and almost one-quarter is a protected area. Portuguese forestry plays a crucial role regarding the three pillars of sustainability:

- a) Economically, as it contributes to the improvement of the national economy and external balance equilibrium. The forest industry is an important exporting sector of tradable goods, contributing positively to the trade balance of the country: forest products account for 12% of total national exports, corresponding to a surplus of €2,395 million; and it has a high gross value added (GVA) – 5.3% of

the GVA of the overall economy and 14% of manufacturing gross domestic product (GDP).

- b) Socially, the forest has the function of a ‘family saving insurance’ and it contributes directly and indirectly to job creation, particularly in disadvantaged areas, contributing to the settlement of populations in these territories. The Portuguese forest sector represents 400,000 owners; 260,000 workers; i.e., 2% of the active population and 9% of industrial employment respectively.
- c) Environmentally, forest ecosystems ensure a set of services such as carbon absorption, enhancing of landscape, conservation of biodiversity, regulation of water quality and the water cycle, curbing of land degradation; the value of which should be on the horizon of sustainable forest management.

Fires are among the biggest threats to Portuguese forests, despite the progress seen in recent years. Indeed, between 2000 and 2009, 35% of the total burnt area in southern European countries (Portugal, Spain, France, Greece and Italy) was in Portugal; additionally, the likelihood of a forest fire in Portugal rose by around 2%, an estimation four times greater than the probability in the other southern European countries; moreover, the resulting cost of fire (27€ per hectare) is 50% higher than the average cost experienced by southern European countries.

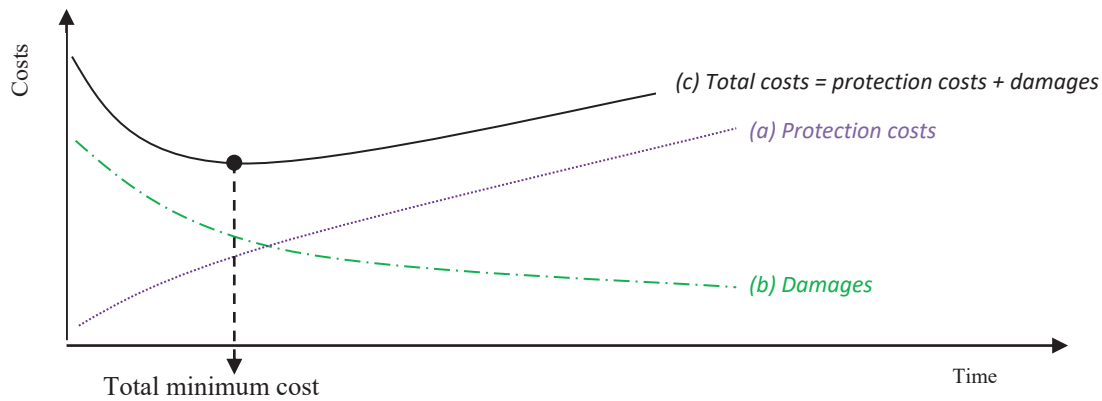
The main objective of this study is to contribute to the understanding of the economic impact of forest fires and its importance for an efficient management of fire costs. The essay begins, in section 2, by discussing the optimal level of protection and the economic and social impacts of forest fires; section 3 offers some methodologies for assessing fire-derived losses in tradable and non-tradable services and goods; and section 4 concludes with a practical work exercise.

## **COST MANAGEMENT OF FOREST FIRES**

The management of forest fires is a matter of efficacy as well as efficiency. As with any other decision regarding the use of limited resources, the efficient management of forest fires must keep its focus on economic principles. Economics says that given the scarceness of resources, economic analysis should be based on choices and the comparison of alternative uses of resources for the choice selection. This comparison

can be carried out by applying cost–benefit analysis or other efficiency analysis, as the criteria of total minimum cost.

Criteria of total minimum cost:  $Min CT = f(\text{protection costs, damages});$   
 $\rightarrow \text{protection costs} = f(\text{prevention, fire fighting costs})$



Source: Adapted from Macedo and Sardinha (1993)

**Figure 1.** The fire total costs function.

When the total cost is at the minimum any increase in investment in prevention and firefighting expenses is not offset by an equivalent reduction in losses, so the difference between benefits and costs is maximized; reaching the point where the marginal costs (prevention + firefighting costs) are equal to the marginal benefits (reduction of losses). In other words, an increase in prevention and firefighting expenses is balanced by an analogous decrease in damages, thus; at that point, the level of protection is optimal.

In summary, the efficient management of forest fire costs should not be primarily focused on the minimization of fire damage but instead the focus should be on the minimization of total costs. In this way, sometimes a decrease in the level of protection, although implying an increase in damage suffered can often be the best economic decision. As an example, in the 1970s, in Britain, the public authorities took the decision to reduce expenses in forest protection, since they were ten times higher than the direct losses caused by fires, and consequently, although experiencing an increase of damage due to the reduction of protection levels, the average total annual costs remained almost unchanged.

An important question in the management of forest fire costs is often the difficulty in assessing their economic impact (Morton et al., 2003). Indeed, forest fires

create a diversity of economic, social and environmental, direct and indirect, short- and long-term impacts, an understanding of which is essential for risk assessment, policy formulation and effective fire management.

Social and economic impacts of fires can be extensive, long-lasting and difficult to identify and assess; e.g. the reduction in property value, tax and income losses for business's, damage to the health of individuals and associated costs, costs due to increased need for water treatment, and costs of non-tradable goods, such as the scenic quality of the landscape, damage to habitats, reduction of biodiversity, climate change, etc. Thus, these have received less attention from researchers than ecological aspects.

In general, only quick statistical data are available, such as the number of fires, how many acres or structures were burnt, and the firefighting costs, which provide an incomplete picture of the total impact of forest fires. Indeed, in the case of large forest fires the environmental, social and economic impacts of the fire can be substantial, particularly when these fires occur in the vicinity of urban areas.

As mentioned, the impact of forest fire can be diverse, including the alteration of wildlife habitat, damage to groundwater and the water supply, damage to public recreational facilities, the evacuation of nearby communities, the breakdown of tourism, destruction of cultural and archaeological sites, the costs of rehabilitation and restoration, and impacts on public health and on transport. However, usually, the more expensive costs are the firefighting costs, damage to residences and the infrastructure and to wood and other forest products. In the next section we will address the question of the assessment of forest fire losses on tradable and non-tradable services and goods.

## **ASSESSMENT OF FOREST FIRE LOSSES**

### **Losses on tradable goods**

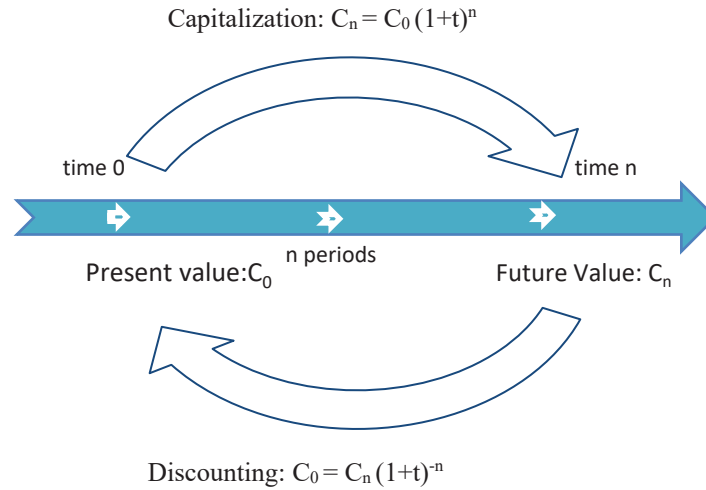
Wood and other forest products; recreational services and equipment and structures.

### **Fundamental concepts**

We begin this section by reviewing some forestry and actual fundamental concepts.

- a) Types of stands: we use the term ‘young forest stands’ if, at the time of the fire, the burnt timber has not yet reached the minimum size to be considered as having commercial value; we use the term ‘aged stands’ or ‘near to the term of exploitability, if, at the time of the fire, the timber is large enough to have commercial value.
- b) Revolution is the lifetime of a stand in years and corresponds to the age of the stand at its final cut.
- c) The term of exploitability refers to the moment when the stand achieves the optimal of economic and / or biological exploitability.
- d) The time value of money principle says that money value can vary over time. For example, a given sum of money today might have a different purchasing power than the same sum of money a couple of years later. The value of money at a future point in time might be calculated by accounting for interest earned or inflation accrued. For example, £100 invested for one year, earning 5% interest, will be worth £105 after one year; therefore, £100 paid now and £105 paid exactly one year later both have the same value to a recipient who expects 5% interest.

Thus, the equivalence between capitals can be achieved through the knowledge of two processes (the inverse of each other): capitalization – the process of finding the future value of a sum ( $C_n$ ) by evaluating the present value ( $C_0$ ); and discounting – the process of finding the present value is using the discount rate ( $t$ ) (see Figure 2 below).



Future value of a present sum (or capital):  $C_n = C_0(1+t)^n$

Present value of a future sum:  $C_0 = C_n(1+t)^{-n}$

Given that:

$C_0$  is the value at time = 0 (present value)

$C_n$  is the value at time = n (future value)

$n$  is the number of periods

$t$  is the discount rate, or the interest rate at which the amount will be compounded in each period.

**Figure 2.** Discounting *versus* capitalization: the time value of money principle.

e) Soil capital (S), is the potential value of 1 hectare of forest soil. The value of S depends on its use ability, the commercial value of the forest species it sustains and the type of exploration and techniques employed. It presumes stands settled accordingly with the techniques appropriate to the season and forest species and are managed according to the appropriated practices and timelines.

The monetary value of 1 ha of forest soil (S) is defined as the capital it would yield during a revolution (N years) plus the interest per ha equal to the difference between actual revenue (R) and expenditures (D) incurred until the term of exploitability, and the discount rate corresponds to the technical growth rate of the forest species installed.

This is:

$$S = \frac{R - D}{(1+t)^N - 1}$$

R – Revenues of the woods at the term of exploitability:

$$R = P + \sum_{n=1}^N (d_n + a_n)(1+t)^{N-n}$$

D – Expenses of the woods at the term of exploitability:

$$D = C_0(1+t)^N + \sum_{n=1}^N e_n(1+t)^{N-n}$$

where:

- ▶  $a_n$  = commercial value of accessory products sold in year n;
- ▶  $C_0$  = installation cost (or initial capital) of 1 ha of burnt forest stand;
- ▶  $d_n$  = commercial value of thinning done in year n;
- ▶  $e_n$  = maintenance and exploration expenses of 1 ha of forest stand in year n;  
if  $e_n$  constante ( $e_n = e$ )  $\Rightarrow \sum_{n=1}^N e_n(1+t)^{N-n} = e \frac{(1+t)^N - 1}{t}$
- ▶  $P$  = market value of the main product at the term of exploitability per ha of forest stand;  $t$  = discount rate (see Tables 1 and 2).

### Losses of cork, resins and fruits

In the case of forestry products that are periodically renewed, once trees have reached a certain age, such as cork, resins and fruits, the losses by area (ha) of forest stand affected by the fire can be calculated, applying one of the following formulas, in case a fire occurs:

Before the start of production:

$$P_p = P_a \times p \frac{(1+t)^a [(1+t)^i - 1] [(1+t)^{N-b} - 1]}{(1+t)^N [(1+t)^a - 1]}$$

After the start of production:

$$P_p = P_a \times p \frac{(1+t)^a [(1+t)^b - 1] [(1+t)^{N-i} - 1]}{(1+t)^{N+b-i} [(1+t)^a - 1]}$$

where:

- ▶  $P_p$  = product loss caused by fire;
- ▶  $P_a$  = annual production per area (ha);
- ▶  $p$  = unit price of the product;
- ▶  $a$  = the period of product renewal: 9 years, in the case of cork; 1 year, in the case of resins or fruits;
- ▶  $i$  = average age of the forest stand at the time of the fire;
- ▶  $b$  = age of the stand at the beginning of production;
- ▶  $t$  = annual growth rate of installed forest species;
- ▶  $N$  = normal revolution of the type of forest stand installed (years).

Table 1 - Technical Growth Rate: Hardwoods						
Revolution (years)	Rapid Growth		Normal Growth		Slow Growth	
	State-owned forests	Private-owned forests	State-owned forests	Private-owned forests	State-owned forests	Private-owned forests
10 ≤ N ≤ 20	0.05	0.06				
20 ≤ N ≤ 30			0.045	0.055		
30 ≤ N ≤ 60					0.04	0.045
60 ≤ N					0.025	0.025

Source: Adapted from Macedo and Sardinha (1993).

Table 2 - Technical Growth Rate: Softwoods								
Revolution (years)	Rapid Growth		Normal Growth				Slow Growth	
	<i>P. radiata</i> <i>P. pinaster</i>		<i>P. pinaster</i>		<i>P. pinaster</i> <i>P. sylvestris</i> <i>P. laricio</i> <i>P. canriensis</i> <i>P. uncinata</i>		<i>P. pinea</i> <i>P. halepensis</i>	
	State-owned forests	Private-owned forests	State-owned forests	Private-owned forests	State-owned forests	Private-owned forests	State-owned forests	Private-owned forests
10 ≤ N ≤ 20	0.055	0.065						
20 ≤ N ≤ 30			0.045	0.050				
30 ≤ N ≤ 60					0.035	0.040	0.025	0.03
60 ≤ N					0.025	0.015	0.015	0.015

Source: Adapted from Macedo and Sardinha (1993).

## Losses of wood

Losses of wood can occur in young stands or in forest stands near to the term of exploitability. In the first case the wood burnt has no commercial value but in the second case the burnt wood includes saleable salvages.

### Fire in forest stands without commercial value

In the case of a fire event in a young forest stand, Capital losses ( $C_L$ ) and Losses for delay of surplus value ( $SV_D$ ) are the commonly used criteria to assess losses. The first one is the criteria used by the Portuguese Institute for Nature Conservation and Forestry (ICNF).

**$C_L$  - Capital losses** per area (ha) of forest stand affected by the fire. It includes the return on soil capital, the capital invested in the setting up and maintenance of the forest stands and respective returns until the fire incident.

$$C_L = K \left[ (S + I)(1+t)^i - S + \sum_{n=1}^i e_n (1+t)^{i-n} \right]$$

**$SV_D$  – Losses for delay of surplus value**, partially or completely destroyed by premature cutting, per area (ha) of forest stand affected by the fire. These losses derive from the fact that gains in woody material resulting from the forest stands' growth in the period between planting and the fire event had been destroyed, thus postponing the term of exploitability in  $i$  years.

$$SV_D = K \times P_N \times V_N \frac{[(1+t)^i - 1]}{(1+t)^N}$$

where:

- ▶  $e_n$  = maintenance and exploration expenses of 1 ha of forest stands in year  $n$ ;
- ▶  $i$  = average age of forest stand (years) at the time of the fire event;
- ▶  $I$  = current cost of setting up 1 ha of the same type of forest stand;
- ▶  $K$  = coefficient of cover (ratio between actual and normal forest stand density for the species, age and season considered);
- ▶  $N$  = normal revolution for the type of forest stand installed (years);
- ▶  $P_N$  = price of wood ( $m^3$ ) at the end of exploitability;
- ▶  $S$  = value of 1 ha of soil capital for forestry use;
- ▶  $t$  = annual growth rate of the forest species installed;
- ▶  $V_N$  = volume of wood per ha obtained during a revolution.

$$\text{if } e_n = e \Rightarrow \sum_{n=1}^i e_n (1+t)^{i-n} = e \frac{(1+t)^i - 1}{t}$$

### Fire in forest stands with commercial value

In case of a fire event in an aged forest stand, **Losses of wood** ( $L_w$ ) and **Expectation value** losses ( $E_v$ ) are the commonly used criteria to assess losses. The last one is the criteria used by the ICNF.

**$L_w$  - Losses of wood** includes the losses resulting from wood commercial depreciation ( $D_w$ ) and from speeding up its cut ( $V_w$ ), by area (ha) of forest stand affected by the fire incident.

$$\text{Loss of Wood} = D_w + P_w$$

**$D_w$  - Commercial wood depreciation** as a result of damage caused in the trunks, which reduce wood value.

$$D_w = P_i \times V_i - P'_i \times V'_i$$

**$V_w$  - Losses in wood volume** from the anticipation of its cut down due to the fire incident.

$$V_w = K \times P_N \times V_N \frac{[(1+t)^{N-i} - 1]}{(1+t)^{N-i}}$$

**$E_v$  - Expectation value** criteria considers the loss of the expectation value of the forest stand at the time of the fire incident, per area (ha) of forest stand affected by the fire:

$$E_v = \frac{K \times R_I - D_I}{(1+t)^{N-i}}$$

**$R_I$  and  $D_I$**  - revenue and expenditure values for the period between the fire and the term of exploitability:

$$R_I = P + \sum_{n=i}^N (d_n + a_n)(1+t)^{N-n} \quad D_I = S \times [(1+t)^{N-i} - 1] + \sum_{n=i}^N e_n (1+t)^{N-i}$$

Where:

- ▶  $a_n$  = commercial value of accessory products sold in year  $n$ ;
- ▶  $d_n$  = commercial value of thinning done in year  $n$ ;
- ▶  $e_n$  = maintenance and exploration expenses of 1 ha of forest stands in year  $n$ ; if  $e_n = e \Rightarrow \sum_{n=i}^N e_n (1+t)^{N-i} = e \frac{(1+t)^{N-i} - 1}{t}$
- ▶  $i$  = average age of forest stand (years) at the time of the fire event;
- ▶  $K$  = coefficient of cover;
- ▶  $N$  = normal revolution to the type of forest stand installed (years);
- ▶  $P$  = market value of the main product at the term of exploitability per ha of forest;
- ▶  $P_i$  = commercial price (per  $m^3$ ) of wood damaged by fire (at most equals to  $P_i$ );
- ▶  $P_i$  = price of  $m^3$  of standing wood with bark, undamaged and with the average characteristics of forest stand burnt;
- ▶  $P_N$  = price of wood ( $m^3$ ) at the term of exploitability;
- ▶  $S$  = value of 1 ha of soil capital for forestry use;
- ▶  $t$  = annual growth rate of the forest species installed;
- ▶  $V_i$  = viable volume of wood that can extract of stems damaged by the fire ( $m^3 / ha$ ) (at most equals to  $V_i$ );
- ▶  $V_i$  = volume of wood of stems damaged by the fire ( $m^3 / ha$ );
- ▶  $V_N$  = volume of wood per ha obtained during a revolution.

### Losses of firewood and brushwood

The losses of firewood in forest stands are obtained by estimating the ratio of the volume of woody stems and crowns and calculating the losses of firewood for the same fraction of wood losses. The assessment of damage for loss of wood is done by calculating the depreciation due to the fire.

### Losses of grasslands

The losses of grasslands are determined according to the location, the normal load, annual income, etc., and include the accumulated annual income of the defence period.

### Losses in hunting

The lack of inventories and the fact that the effect of fires on hunting extends to five years make it difficult to estimate the hunting losses caused by fire. Moreover, the recreational character of hunting activity inhibits the estimation of the commercial value or the number of pieces culled annually. In the case of having such estimates the huntable losses caused by fire can be calculated by:

$$H_n = \frac{\sum_{i=n-4}^n Am_i}{A_m} \times V_n$$

where:

- ▶  $H_n$  = damage caused by brushwood fires on hunting in year n;
- ▶  $Am_i$  = area of burnt brushwood in year i;
- ▶  $A_m$  = total area of brushwood in the region or country;
- ▶  $V_n$  = commercial value of the hunting in year n.

### Losses in recreational services

Forest fires produce, among others, effects on soil, vegetation, fauna and microclimate, some of which last for decades. The recovery of the landscape and its recreational and touristic value, after a fire, is a task for the long term and may even take as long as 20 years, especially in forests with slow-growing species. Losses in recreational services can be determined by:

$$P_{rn} = 0,65 \times \left[ R_{fn} \sum_{i=n-19}^n A_{fi} + R_{mn} \sum_{i=n-4}^n A_{mi} \right]$$

where:

- ▶  $P_{rn}$  = damage caused by the fires in recreational values in year n;
- ▶  $R_{fn}$  = annual revenues of 1 ha of forest in year n;
- ▶  $R_{mn}$  = annual revenues of 1 ha of bushes in year n;
- ▶  $A_{fi}$  = area of burnt forest in year i;
- ▶  $A_{mi}$  = area of bushes burnt in year i.

### **Losses in infrastructure and equipment**

In the case of repairable damages, the losses are evaluated by the cost of the repair. In the case of destruction, damages are determined by:

$$P_b = \left(1 - \frac{i}{v}\right) \times p$$

where:

- ▶  $P_b$  = damage caused by fire to the infrastructure or equipment;
- ▶  $i$  = age of the infrastructure or equipment at the time of the fire;
- ▶  $v$  = standard lifetime of the equipment or the infrastructure (see table 3 next page);
- ▶  $p$  = original cost of the infrastructure or equipment.

**Table 3 – Infrastructures and equipment’s average lifetime**

Property	Average lifetime (years)	Property	Average lifetime (years)
<u>Transportation</u>		<u>Buildings</u>	
- Aircraft	6	- Factories, garages, warehouses, offices, etc.	45
- Passenger cars, motorcycles, trailers	3	- Recreational facilities	20
- Buses	9	- Countryside residences	25
- Light trucks	4	<u>Crops and Livestock</u>	
- Heavy trucks, tank trucks, tractors	6	- Annual crops	1
<u>Betterments</u>		- Orchards, vineyards, etc..	10
- Roads, canals, ditches, piers, bridges	20	- Livestock	1
- Fences	10		
<u>Infrastructure and Equipments</u>			
- Buildings (excluding residences)	25		
- Agricultural machinery	10		
- Mining constructions	10		
- Machinery and equipment for forestry	6		
- Sawmills and other permanent units	10		
- Pulp industries	15		

Source: Adapted from Macedo and Sardinha (1993).

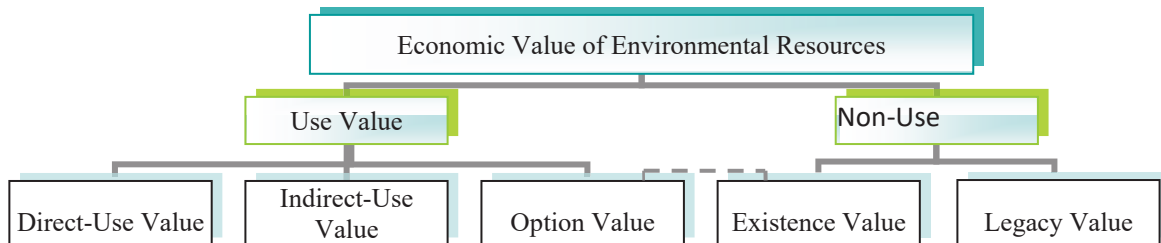
### **Losses on non-tradable goods: The economic value of environmental goods and resources**

As mentioned, the impacts of forest fire can be diverse, including losses of non-tradable goods, such as the scenic quality of the landscape, damage to wildlife habitats, and reduction of biodiversity. The economic assessment emerges as a measuring tool of environmental goods and services and of the impacts of environmental degradation and depletion, determining the direct and indirect costs of qualitative and quantitative changes. It is gathering importance in the evaluation of forest fire economic losses on non-tradable goods.

The economic value of a good refers to the maximum quantity of other goods and services that people are willing to give in exchange of a good, a service or a 'state of the world' (e.g. environmental quality). This definition highlights that goods or services only have value if people assign it to them, and that value concept is relative and is measured through an exchange (of goods and services).

The economic value of an environmental good consists of the estimate of a monetary value for this good, in opposition to other available goods. However, sometimes, it is difficult to aggregate all the effects in a single indicator. The economic value of environmental resources (EVER) results from their attributes, and these can be associated to the use (direct, indirect and option) or non-use of the resource, i.e., its simple existence (Figure 3). EVER proposes a fee for environmental resources' use and/or preservation. The genesis is the protection of current and future generations' interests. Thus, use value (UV) is the value attributed by people who use or have the usufruct to the environmental good to satisfy their needs. The non-use value (NUV) is dissociated from the use because it derives from a moral, cultural, ethical or altruistic position regarding the rights of existence of other living species or the preservation of natural assets even if they do not represent current or future use for them. While slightly different classifications exist, these produce the same result. Still, controversy exists regarding existence (EV) and option (OV) values, since the EV represents the individual will to preserve a set of environmental resources for future generations' direct and/or indirect use. Thus, the conceptual question is whether a value defined in this way is closer associated with the OV or the EV. Equally, the legacy value (in this definition

mixed with the EV) can be independent (Figure1). However, for EVER it is important that the individuals point out the most trustworthy values possible, independently of the current or future use.



**Figure 3.** Different economic values of environmental resources

How to quantify an intangible asset such as ‘air quality’? The answer to this question resides in the concepts of:

- a) Sacrificed Production – this measures the value, at market prices, of the production that ceases to be produced as a result of actions harmful to the environment caused by other activities;
- b) Willingness to Pay – this refers to individuals’ willingness to pay for the additional consumption of the environmental good; it is used when the environment good has not only a current market value but also a future use value (VO) and an existence value (VE).

There are several methods of economic valuation of environmental goods and resources; the most commonly used for assessing forest fire impacts are market prices, hedonic prices, travel costs, transference of benefits and contingent valuation methods. Table 4 presents a summary of these methods.

**Table 4 – Methods of economic valuation of environmental goods and resources**

Market prices	Estimation based on the price at which goods and services are traded in markets. It can be used to assess changes in the quantity or quality of a good or service. Example: losses in wood, structures and equipment; carbon exchange market.
Hedonic prices	This is based on the premise that the market price of a given product reflects the set of characteristics or the services it provides. It values individual characteristics by analysing the variation in market price to changes in their characteristics. Example: losses in non-tradable assets such as the scenic quality of a landscape can be measured through variations in the market price of a given house located in a burnt area prior and after the fire event.
Travel costs	The time and expenses that a person spends in travelling, for example, to a recreational area, represents a measure of the price that individuals paid to access that location. It's usually used in the valuation of environmental resources such as parks and other recreation areas.
Transference of benefits	This method produces an estimate of benefits using existing information concerning studies at other locations and / or settings. It is often used when it is too expensive and / or there are strong constraints to a specific study of a certain place.
Contingent valuation	<p>This method consists of asking people directly, through a questionnaire, how much they are willing to pay for a particular environmental good or service or, in some cases, how much they are willing to accept to give up the usufruct to a particular environmental service. It is a way to allocate money value to the non-use of environmental goods; i.e. goods and resources that do not involve market transactions and that may not involve direct participation, only 'passive use' value.</p> <p>Example: The value of enjoying the scenic landscape and observing wildlife; the value given to the possibility of future fishing or watching birds, and the right to bequeath these options to future generations, or the value that people attach to simply knowing that there are whales or giant pandas.</p>

Table 5 presents some examples of the economic impact of forest fires.

**Table 5.** Economic impact of forest fires

Damage Category	Asset	Value (€)	Method Used	Country	Reference
Forestry Goods and Resources	Timber	€322–551 million	Market prices	USA	Mercer et al. (2000)
	Timber	€467 million	Market prices	Indonesia	EEPSEA (1998)
	Direct forest benefits	€667 million	Transference of benefits	Indonesia	EEPSEA (1998)
	Indirect forest benefits	€1.019 million	Transference of benefits	Indonesia	EEPSEA (1998)
	Biodiversity	€28.4 million	Contingent valuation	Indonesia	EEPSEA (1998)
	Carbon absorption	€257.4 million	Market prices	Indonesia	EEPSEA (1998)
	Habitats	€43 and €74	Contingent valuation	USA	Loomis and Gonzalez-Caban (1998)
Property Losses		9-11 million €	Market prices	USA	Mercer et al. (2000)
	Private property	20 million €	Market prices	USA	Mercer et al. (2000)
	Infrastructures	742.900 €	Market prices	USA	Kent et al. (2003)
Losses in Economic Activity	Tourism	70.3 million €	Market prices	USA	Mercer et al. (2000)
	Sales	Increased 1,000 million €	Official statistics	USA	Mercer et al. (2000)
	Salaries	Decreased 3%	Official statistics	USA	Kent et al. (2003)
	Sales	Increased 4%	Official statistics	USA	Kent et al. (2003)
Other Damage	Health problems	€ 946 million	Market prices, contingent valuation	Indonesia	Ruitenbeek (1999)
	Emergency calls	Increased from 91% to 132%		USA	Mercer et al. (2000)
Rehabilitation after Fire	Emergency rehabilitation	€11.8 million	Market prices	USA	Kent et al. (2003)
	Long-term rehabilitation	€31.2 million	Official statistics	USA	Kent et al. (2003)

Source: Adapted from Riera et al. (2006).

**PRACTICAL WORK EXERCISE**

A wildfire has devastated a mixed forest comprising 5 ha of pinewood from natural regeneration, and 10 ha of cultivated land of chestnut trees located on private property. The pinewood was aged 12 years and there was no commercial recovery of the burnt wood. The chestnut trees were aged 25 years and it was possible to recover €750 per ha of salvaged wood. The damage suffered included losses of wood and fruits.

**1. Determination of chestnut tree wood losses**

Chestnut tree summary table:

Area = 10 ha	$C_0 = €500 /ha$	$N = 40$ years	$i = 25$ years	$e_n = e = €25 /ha$
$V_N = 100 \text{ m}^3 /ha$	$P_N = 37.5€$	$V_i = 55.5 \text{ m}^3 /ha$	$P_i = €20$	Salvages = €750 /ha
$t = 0.04$		$a_n = 0$	$K=0.6$	

	Year (n)	Volume/ha ( $\text{m}^3$ )	Price / $\text{m}^3$
Thinning scheduled	15	15	10
	20	18	15
	25	20	22.5
	30	25	27.5

→ **Loss of Wood**

Commercial wood depreciation – Fires in forests aged near to the term of exploitability cause damage to trunks, which can substantially reduce the commercial value of the wood.

The commercial depreciation of the wood is given by:

In the present case salvages  $\text{salvages} = P'_i \times V'_i \Rightarrow D_W = 55.5 \times 20 - 750 = 360€$

$$D_W = P_i \times V_i - P'_i \times V'_i$$

Losses in wood volume from the anticipation of its cut down due to the fire

$$V_W = K \times P_N \times V_N \frac{[(1+t)^{N-i} - 1]}{(1+t)^{N-i}} = 0.6 \times 37.5 \times 100 \times \frac{[1.04^{40-25} - 1]}{1.04^{40-25}} = 2,250 \times \frac{0.8009}{1.8009} = 1,000.60\text{€}$$

**Loss of Wood** =  $D_w + P_w = 1,360.6$  per ha, making a total of about €13,606.25 for the 10 ha of chestnut trees burnt.

→ **Expectation value (EV)**

$$EV = \frac{K \times R_I - D_I}{(1+t)^{N-i}} = \frac{0.60 \times 5,578.04 - 878.46}{1.8009} = 1,370.63\text{€}$$

The revenue and expenditure planned for the period between the fire and the term of exploitability are:

$$R_I = P + \sum_{n=i}^N (d_n + a_n)(1+t)^{N-n} = 3,750 + 810.40 + 1,017.64 = 5,578.04\text{€}$$

$$D_I = S \times [(1+t)^{N-i} - 1] + e \times \frac{(1+t)^{N-i} - 1}{t} = 471.81 \times (1.04^{15} - 1) + 25 \times \frac{(1.04^{15} - 1)}{0.04} = 878.46\text{€}$$

Determination of Soil Capital:  $S = \frac{R - D}{(1+t)^N - 1} = \frac{6,569.51 - 4,776.14}{1.04^{40} - 1} = \frac{1,793.34}{3.801} = 471.81\text{€}$

$$R = P + \sum_{n=1}^N (d_n + a_n)(1+t)^{N-n} = 3,750 + 2,819.51 = 6,569.51\text{€}$$

$$P = 100 \times 37.5 = 3,750\text{€}$$

$$\sum_{n=1}^N (d_n + a_n)(1+t)^{N-n} = 2,819.51$$

Year (n)	Volume (m <sup>3</sup> )	Price / m <sup>3</sup> (€)	d <sub>n</sub> (Volume x Price)	(1+t) <sup>N-n</sup>	d <sub>n</sub> × (1+t) <sup>N-n</sup>
15	15	10	150€	1.04 <sup>40-15</sup> = 2.6658	399.87€
20	18	15	270€	1.04 <sup>40-20</sup> = 2.1911	591.60€
25	20	22,5	450€	1.04 <sup>40-25</sup> = 1.8009	810.40€
30	25	27.5	687.5€	1.04 <sup>40-30</sup> = 1.4802	1,017.64€
Total					2,819.51€

$$D = C_0(1+t)^N + e \times \frac{(1+t)^N - 1}{t} = 500 \times 1.04^{40} + 25 \times \frac{1.04^{40} - 1}{0.04} = 24,776.14\text{€}$$

**Expectation Value Losses:**  $EV - Salvages = 1,370.63 - 750 = 620.63\text{€}$  per ha, making a total of about €6,206.3 for the 10 ha of chestnut trees burnt.

## 2. Determination of chestnut fruit losses

Chestnut fruits summary table:

$P_a = 7,500\text{ kg}$	$a = 1\text{ years}$	$b = 10\text{ years}$	$p = 2\text{€}$	$N = 40\text{ years}$	$i = 25\text{ years}$	$t = 0.04$
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### → Chestnut fruit losses

$$P_p = P_a \times p \frac{(1+t)^a [(1+t)^b - 1] [(1+t)^{N-i} - 1]}{(1+t)^{N+b-i} [(1+t)^a - 1]} = 7,500 \times 2 \frac{(1.04) [(1.04)^{10} - 1] [(1.04)^{15} - 1]}{(1.04)^{25} [(1.04) - 1]} = 562,723.710\text{€}$$

**Chestnut fruit losses** equal €112.54 per ha, making a total of about €5,627,237.10 for the 10 ha of chestnut trees burnt.

## 3. Determination of pinewood losses

Pinewood summary table

$A = 5\text{ ha}$	$K = 0.8$	$e_n = e = 25\text{ € /ha}$	$d_n = 0; a_n = 0$	$N = 50$	$i = 12\text{ years}$
$V_N = 200\text{ m}^3/\text{ha}$	$P_N = 35\text{ € /m}^3$	$I = 5,000\text{ € /ha}$	$C_0 = 0$	$t = 0.04$	

### → Capital losses ( $C_L$ )

$$C_L = K \times \left[ (S + I)(1+t)^i - S + e \frac{(1+t)^i - 1}{t} \right] = 0.8 \times \left[ (521.28 + 5,000) \times 1.04^{12} - 521.28 + 25 \times \frac{1.04^{12} - 1}{0.04} \right]$$

$$= 6,955.13\text{€}$$

Determination of Soil Capital:  $S = \frac{R - D}{(1+t)^N - 1} = \frac{7,000 - 3,816.68}{1.04^{50} - 1} = 521.28\text{€}$

$$R = P + \sum_{n=1}^N (d_n + a_n)(1+t)^{N-n} = 200 \times 35 = 7,000\text{€}$$

$$D = C_0(1+t)^N + e \times \frac{(1+t)^N - 1}{t} = 25 \times \frac{1.04^{50} - 1}{0.04} = 3,816.68\text{€}$$

**Capital losses** equals €6,955.13 per ha, making a total of about €34,775.70 for the 5 ha of pinewood burnt.

→ **Losses for delay of surplus value (SV<sub>D</sub>)**

$$SV_D = K \times P_N \times V_N \times \frac{[(1+t)^i - 1]}{(1+t)^N} = 0,8 \times 35 \times 200 \times \frac{[1,04^{12} - 1]}{1,04^{50}} = 56,000 \times \frac{0,601}{7,107} = 473,56\text{€}$$

**Losses for delay of surplus value** equals €473.56 per ha, making a total of about €2,367.81 for the 5 ha of pinewood burnt.

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