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Social risks of forest fires: a methodological proposal for their monetary evaluation

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Social risks of forest fires: a methodological proposal for their monetary evaluation[1]

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Abstract: The risk of forest fire in Portugal ranks among the highest in Europe. In recent times, fears have risen over the incidence of major forest fires with a scale and dimension that generate extremely high economic, environmental and social costs. Combatting this type of fire represents a particularly difficult and expensive objective and, in some cases, with a far from desirable level of efficiency. Particularly due to the national context characterised by severe budgetary restrictions, guaranteeing greater effectiveness and efficiency in forest fire prevention and fighting represents core objectives. One of the ways of improving the decision making process involves the monetary estimation of the total costs caused by fires and their respective risk levels, thus the cost of the risk of fire (in the sense of the economic cost calculated from the perspective of society in contrast to the concept of economic cost calculated according to the private ownership perspective) and that includes the probability of the incidence of fire and its propagation and the total cost of the damage that incorporates both the specific social costs, the economic cost and the environmental cost. This working paper holds the objective of contributing towards the conceptual and methodological discussion around this theme.

Keywords: forest fires; social cost; monetary evaluation; methodology.

JEL: Q23; Q51.

1. Introduction

Forest fires are characteristic of the natural dynamics of ecosystems producing forestry resources in the Mediterranean basin and, correspondingly, are equally typical of Portuguese forests, annually marking their presence while varying both in number and in intensity. However, from the early 1990s onwards, there has been a rise in both the number and frequency of major forest fires that became the direct cause of enormous losses and economic, social and environmental damage.

The characteristics of forest fires in Portugal have been broadly documented in various studies. Portugal forms part of the five member group of EU states most afflicted by forest fires –

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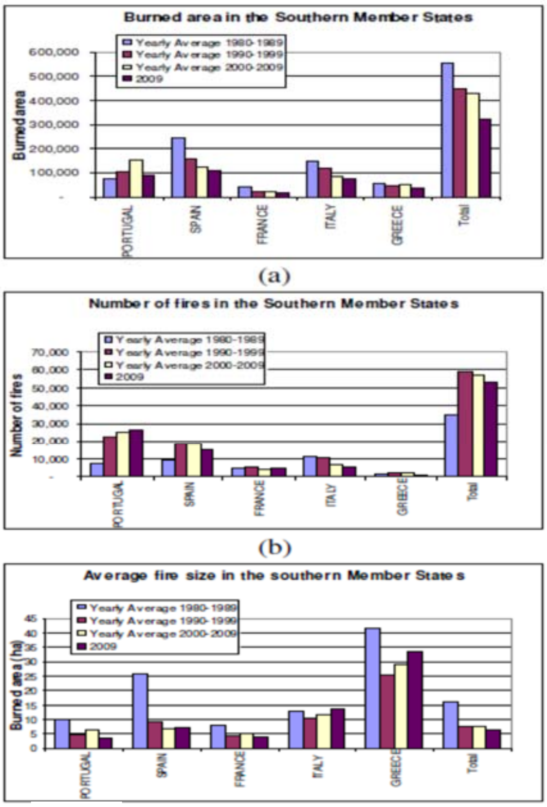
alongside Spain, France, Italy and Greece. The largest average contribution made towards the total for these five countries over the 2000-2009 period, whether in terms of the number of fires or the areas burned, was Portugal with 44% and 35% respectively (Tables 1 and 2 in the Annex).

To gain a reasonable understanding of the scale of these events in Portugal, we may, for example, refer to 2009 when there were 26 119 incidences in the country resulting in the burning of 87 416 hectares of grasslands and forest in contrast to only 19 749 incidences and 18 472 hectares burned in 18 other European states, including Turkey (JRC 2009). Figure 1 sets out the total of areas burned and the number of fires for the five countries of southern Europe and the respective averages across three periods of time.

Figure 1 International Comparisons

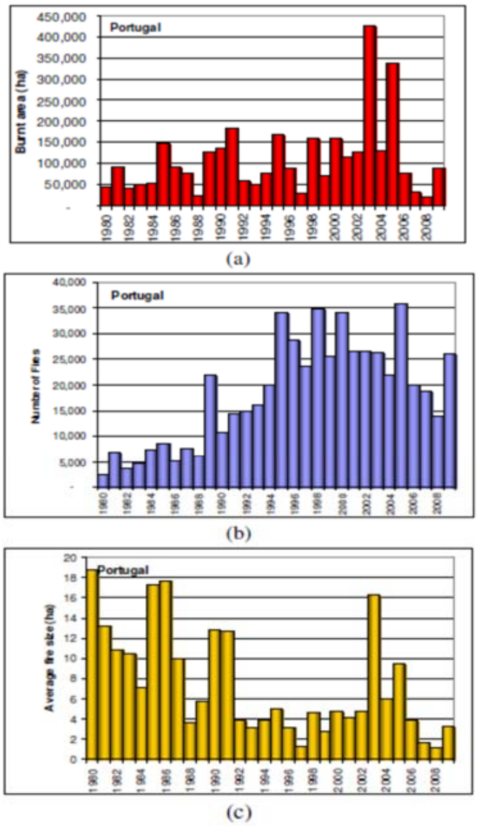


Burnt areas (a), number of fires (b) and average fire size (c) in the five Southern Member States in the year 2009 as compared with average values for previous decades.

Source: JRC 2009.

Nevertheless, these comparisons do not hold at the absolute level given that the areas of countries and the areas at risk of fire are very different from country to country. However, we may certainly conclude, for example, that these statistics display significant variations from year to year that reflects the importance the climate factor has on the extent of occurrences and hectares burned. Portugal does indeed represent a good example of this influence: in the final decade of the last century, the years of 2003 and 2005 saw the highest number of fires and hectares burned and the largest average scale of the fires (Table 3A of the Annex), which stems to a large extent from having been the two years afflicted with the most severe droughts; however, in the period between 2007 and 2011 (with the exception of 2009 and 2010), the area burned in Portugal dropped significantly as regards the preceding years, which in turn derives from the climate having experienced particularly precipitous years. Figure 2 clearly displays the two peaks corresponding to the areas burned in 2003 and 2005 and the rising trend (even while clearly attenuated by the aforementioned beneficial climate factors) contributing towards the number of outbreaks in those two years. 85% of the areas burned took place due to large scale forest fires (DGRF 2007).

Figure 2 - Area Burned and Fire Numbers in Portugal



Burnt areas (a), number of fires (b) and average fire size (c) in Portugal for the last 30 years.

Source: JRC 2009

Another of the characteristics of forest fires in Portugal encapsulates their concentration around urban areas (Figure 3); the majority of the areas burned fall into the interface zone between urban and rural areas (Figure 4).

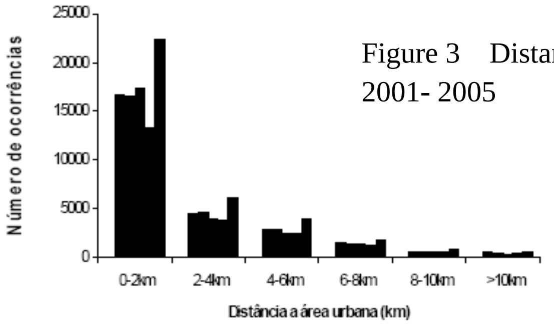
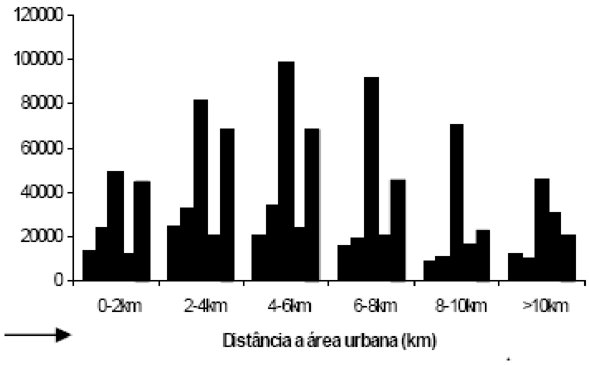


Figure 3 Distance of fires to urban areas 2001- 2005

Source: DGRF, Forest Fires Report 2006

Figure 4 Distance of Area Burned to Urban Area



Source: DGRF, Forest Fires Report 2006

The causes behind this rapid worsening in the number and the scale of forest fires both in Portugal and in the Mediterranean basin, particularly in climate conditions characterised by periods of prolonged drought, and their increasing proximity to urbanised areas, are multiple but susceptible to grouping into three categories. The first group of causes includes the dramatic alterations in the socioeconomic foundations of forested regions over the course of recent decades. Such alterations broadly feature the decline and practical disappearance of the traditional agricultural and agro-forestry sector, the ageing and abandoning of forested zones by the local population, especially in the North and Centre of the country. In addition to this scenario of advancing economic and human desertification, there also comes the contribution made by ongoing globalisation to the extent that this favours more intensive and more industrial agricultural practices – based fundamentally on the highly intensive and temporally concentrated exploration of the soils and water – which therefore correspondingly drives the abandonment of traditional agricultural practices in regions where they prove less productive. There are also other additional factors that have contributed towards raising the likelihood of fires starting, as well as the frequency, intensity and extent of forest fires. Such factors include: the electricity distribution infrastructures located in forested areas; means of transport running through forests; the presence of urban populations in forested areas for purposes of recreation and leisure; the rising level of urban concentration;

thus the pressures that economic activities making recourse to forestry products as productive inputs place upon forest management, especially the type of forest planted.

The second group of causes includes the swift advance of ongoing climate change both in Portugal and in the entire Mediterranean region and the geomorphologic characteristics of the forested regions. The climate has experienced a period of great instability: increasingly long periods of drought take place ever more frequently interspersed with periods of torrential rain. On average, forecasts point to an increase in temperatures and a decrease in precipitation. Furthermore, in addition to the climate change forecasts for mainland Portugal, there are also the other local and seasonal climatic factors that heighten the risk of forest fires. This is the case with the prevailing winds, for example. The winds normally blow in a Northerly direction during the heat of summer. Locally, they may blow according to random, anarchic regimes, characterised by unforeseeable oscillations and very swift changes in the wind directions coupled with accentuated variations in both the frequency and intensity of gusts. These climate phenomena, and alongside the other factors contributing towards the increased risk of forest fires, have come to transform forest fires in Portugal into local, regional and national tragedies, with high levels of economic (quantifiable through market prices), social and environmental (rarely – or never – quantified monetarily due to the lack of any markets enabling their direct evaluation) costs. The geomorphologic conditions in some forested regions, characterised by sharp and very steep slopes rendering overland access very difficult and with the lack of points of water supply further compounding the problems for fighting forest fires in such areas.

Finally, the third group of causes includes the rights of ownership over the forest, forest management policies, prevention strategies and policies and forest firefighting policies. As regards forest management, the main factors of risk stem from the existence of extensive and unbroken areas of single species forest, such as eucalyptus and pine, that proves highly vulnerable to fire; and the property holding regime – characterised by the prevalence of small landholders with their miniscule properties further fragmented by the prevailing geographic conditions, by the existence of poorly defined or outdated property rights and duties and the low levels of forestry profitability (which have also in the meanwhile accelerated their decline due to the persistent and cyclical nature of fires in the most affected regions). One of the consequences of this situation is the non-existence of effective forestry management policies, especially those inappropriately tailored to zones in which small landowners account for the bulk of the forested area. Furthermore, there also remains a fairly lax culture among local populations reflecting both in the failure to take the legally stipulated preventive measures and in their risk causing patterns of behaviour.

All of these causes have contributed towards raising the quantity of accumulated biomass. This growth has in turn sped up due to the following series of factors. First and foremost, by the replacement of traditional, low productivity agriculture either by spontaneous vegetation and brush land, or by forestry species that attain high growth rates and guaranteed market values, such as eucalyptus. Secondly, by the territorial spread of the monoculture defined by the planting of areas of forest made up of high growth species that nevertheless remain more vulnerable to fire – maritime pine and eucalyptus -, to the detriment of indigenous species, slower growing but more resistant to fire. Thirdly, due to the growing human desertification. And, finally, due to the ongoing changes in the prevailing climate and the specific local conditions. The fast growing species, in addition to failing to provide resistance to fire, also contribute greatly towards boosting the intensity and speed with which forest fires spread in a factor still only worsened by the aforementioned climate changes.

Within this framework, the prevention and combat policies that have been adopted in Portugal have unfortunately demonstrated their widespread inadequacies as regards avoiding blazes and controlling or at least limiting the destruction associated with large fires, especially those breaking out during years of heightened climate risk.

The major forest fires are responsible for intensive and extensive destruction, which interlinks with extremely high and varied levels of ecological, economic and social losses of considerable monetary value that are not only incurred during the fire itself but also over a temporal period that extends far beyond the putting out of the fire. Burned wood and timber holds a lower market value. Homes and infrastructures remain damaged or destroyed. Both the wood based and the other non-timber forest based products, such as cork, mushrooms, honey, herbs and plants for medicinal, culinary or industrial purposes, for example, are also subject to either destruction or non-production with the corresponding negative outcomes. The families and individuals who regularly use the forested environments to produce and benefit from recreational services experience a downturn in their wellbeing over the short, medium and long terms all the while the ecosystems have yet to recover. The prevailing biodiversity gets destroyed or damaged, which reflects in the loss of natural environments and, in some cases, the irreversible destruction of the species, especially whenever forested areas of great ecological wealth and under legal protection get burned down. Forest fires cause damage, to a greater or lesser extent irreversible, in the biological functioning of the forestry ecosystems, which negatively influences their natural capacities for self-regeneration and, therefore, for sustainability. The carbon stored in the tree trunks, branches, leaves and roots gets released into the atmosphere. The ecological services naturally produced by the forest ecosystems are thrown into jeopardy. The dangers of soil erosion rise significantly; the quality of natural services regulating the surfaces and subterranean hydrological systems supplied by the forest ecosystems are also at risk in addition to cutting back on the fixing of greenhouse gas emissions and levels of oxygen production.

Among the persons who are directly or indirectly impacted on by the fires, these include not only the local populations but also those in adjoining regions, national and international populations and as well as the respective fire crews. The local populations and fire fighters, beyond their exposure to direct material losses and damage, are also subject to suffering other types of losses and damage, whether directly associated with the fire or indirectly, such as through inhaling the smoke and pollutants it contains (smut, carbon monoxide, carbon dioxide and other greenhouse gases).

In addition to the direct losses and damages to the properties and infrastructures, the fires also impact on the economic foundations of the regions affected. There may be decreases in revenues from tourism and from primary activities (agriculture, forestry, hunting and fishing) and for the manufacturing sector, especially those units depending on environmental products as core inputs into their productive activities. In addition to the loss of revenues, there may also be the loss of employment coupled by a slide in local retail sales. Whenever the respective region has a poorly diversified economy and is excessively dependent on tourism and/or the production of timber and non-timber based products, for example, then local economic sustainability suffers serious impacts over the short and long terms.

Whenever a forest fire breaks out, society has to incur additional costs directly related with its combatting. Subsequently, these costs expand to also include the clean-up operation and the regeneration of the area burned as well as the costs of preventing soil erosion and the contamination of watercourses. Therefore, the economic, environmental and social damages and losses associated with forest fires vary over their timeframes: impacting in the short term, during the fire itself, while the social costs of major fires extend over the medium and long terms as they stretch far beyond the extinguishing of the fire and for highly disparate periods of time depending on the extent and nature of the losses and damages.

The forest is an ecosystem of recognised economic, social and environmental importance. However, the economic evaluation of the risk of forest fires has received very little attention whether from economists, technical specialists or decision makers despite the rising need experienced for the monetary evaluation of the damages and losses associated with this type of incidence and alongside the net benefits of measures for combatting and preventing fires (Rideout and Ziesler 2004).

Despite economics remaining relatively underused in the study of forest fire associated themes and their respective risk management, these have nevertheless been subject to regular study within the scope of other academic fields, for example studying the types of ignition, analysing and predicting the patterns of fires at the local and global scales while also calculating the respective risks of fires breaking out and propagating. Nevertheless, the socio-environmental alterations currently ongoing in the Portuguese regions hosting forests have greatly contributed towards the risk of the occurrence of large forest fires in these regions, in conjunction with the rising level of expenditure incurred by state entities in defining, implementing and managing fire prevention and combat policies, transforming forest fires into a factor of critical social risk, of difficult but necessary management and, as such, a priority objective in the efficient management of natural forest resources. The uncertainty that surrounds the peak period in terms of the number, intensity, level of danger and magnitude of the damage associated with forest fires, substantially hinders the task of preventing and planning the means of combat as well as of financing by the government authorities in order to deal with the needs arising in years of catastrophe. Hence, the risk management of forest fires requires approaching as a priority objective in prevention policies. One of the measures necessary to this efficient management derives from evaluating the social costs of forest fire risks; hence, the cost of fire risks calculated from the perspective of the interests of society – thus, economic, environmental and social –, in contrast to the calculation of fire risk costs from only the perspective of private interests. The other measure integrates the definition and choice of prevention policies and more effective means of combatting fires from the economic point of view and deployed with more effective means to reduce the scope of destruction that is perceived to be on the rise.

Only very recently (and still somewhat timidly) have economists turned their attentions to these matters through the production of economic studies with two types of core objectives (Riera 2005):

i) Some quantify in monetary terms the costs associated with fires (Kline 2004, Prestemon *et al* 2004, Kent *et al* 2003, Mercer *et al* 2000, or EEPSEA 1998, for example);

ii) Others evaluate the economic efficiency of some of the fire risk prevention means, such as reducing the amount of combustible materials in such areas made with recourse to fire prevention techniques (Kline 2004, Riera and Mogas 2004, Rodriguez and Silva 2004, Prestemon *et al* 2001, Loomis *et al* 2003, or Cleaves *et al* 2000, for example); and while others evaluate the economic efficiency of measures to combat the fires that do break out (for example, Mendes 2010 applies the producer theory to determine the economically efficient technical choices for combatting forest fires; Rodriguez and Silva 2007 deploy economic methodologies and theories to choose the methods and techniques for more efficiently preventing and combatting fires).

The studies evaluating the economic costs of fires are greater in number but, nevertheless, still only attain a relatively modest total and, in their majority, estimate only the damage associated with the fires and rarely with their totality, hence, with their social costs. The proportions making up the costs taken into consideration by the different evaluation studies for the costs of forest fires vary substantially from study to study and in accordance with their respective individual objectives. This relative scarcity of studies, on the one hand, combines with the partial nature of their objects of study in the majority of cases and, on the other hand, this above all explains the difficulties associated with the empirical exercise of valuation, which includes such core factors as obtaining reliable and sufficient statistical information and as well as the need to apply valuation techniques, some of which contain great technical complexity. The second type of economic study contains those evaluating the level of efficiency and effectiveness of preventive measure such as the collection of forest combustibles or the practice of preventive burning, for example. However, this also includes works evaluating the impact of the resources spent on prevention towards the actual reduction of fire risks and the impact of the resources allocated towards combatting fires, within the scope of which come evaluations as to whether the expenses incurred by society in prevention and combat turn into positive net benefits for society.

Despite the social and economic gravity that forest fires pose to Portugal – especially in years with higher levels of climatic risk – economic analysis studies of this type of occurrence and its effects, and along with similar studies on the efficiency of the protective and combat measures, remain practically non-existent. Through to the date of this work, there has only been one Portuguese reference to an apparently economic approach to the cost of forest fires, integrated within the scope of the National Plan for the Defence of Forests Against Fires (*Plano Nacional de Defesa da Floresta Contra Incêndios*). Following these findings, we thus decided that the main objective of this work would be to contribute towards the definition and clarification of the concept of the economic costs (from society's perspective) of forest fire risks and discussion of the proportions of costs that should duly be included in future economic studies no this theme. According to economic theory and the Cost-Benefit Analysis methodology, this should only take into account those fire costs deemed *relevant*. By *relevant costs*, we understand all of the costs associated with the losses and damages directly caused by the fire when this effectively breaks out and spreads. Nevertheless, the characteristic of "*relevant*" when applied to costs has no precise definition and remains dependent on the evaluation perspective of each decision maker/actor affected by forest fires and the consequences in terms of costs. For example, the perceptions of forest owners without any insurance about the cost of a fire that destroyed their properties is not the same as a fellow owner with an insurance policy; the cost of fires calculated from the perspective of the fire service that fights the blazes differs from the costs of fires evaluated from society's perspective; the perceptions of the costs incurred by a private forest owner do not coincide with the perceptions that society holds over those same costs.

The choice of this object of study for this present work stems from the simple fact that evaluating the cost of forest fire risks is, in sum, the common denominator to the three main challenges facing the forest fire risk prevention policies that we described above.

The study structure is the following. In section 2, we begin by defining the concept of forest fires risk before, in section 3, discussing the method applied to calculate the costs associated with forest fires risks from the perspective of society. In section 4, we present some examples of estimates of the monetary costs of forest fires existing in the literature even while without ever attempting an exhaustive review. Finally, in section 5, we set out our conclusions.

2. The Concept of Fire Risk Cost

The concept of fire risk has not been subject to any clear definition in the respective literature. There is, therefore, the need for clarification[3]. If we were in the presence of two states[4] that produce different results or occurrences (thus, in this case, either "there are no fires" or "there are fires"), then we may propose that there is a situation of *risk* for at least one of these outcomes represents a loss: in this case, whenever there is a fire (an occurrence), a determined number of hectares of forest burns and, there are immediately the losses associated with these burned hectares. This scenario defined in accordance with the losses and/or damages caused by the occurrence – the fire – gets designated as a *bad state*. If there are no occurrences and the forest does not burn and the losses of the bad state are thereby avoided – then this scenario gets defined by the non-occurrence of fires and, therefore, of losses, and correspondingly designated a *good state*.

The losses and/or damage associated with the fire risk are subject to quantification either in physical units (hectares burned, number of lives lost, for example) or in monetary units. Nevertheless, this quantification of losses in monetary units requires some knowledge about the amount of losses as measured in physical units.

The causes associated with the occurrence of the bad state are the *factors of fire risk*, which are determinant to the scale of the losses and the damage. Both states, the g*ood* and the *bad*, are uncertain and hence occurring randomly: the *good* state occurs with a probability of ρ while the *bad* states holds a probability of $(1-\rho)$ and hence $\rho + (1-\rho) = 1$. Whenever the probability of the occurrence is objectively understood then we are able to affirm that we are facing a situations of *risk*. On the contrary, whenever the probability of the occurrence remains subjective, then we may state that we are dealing with a situation of *uncertainty* (Kolstad, 2000). Whenever the probability of the occurrence proves objective and the value of the losses associated with the occurrence (the *risk of fire*) may be evaluated monetarily, then we are referring to the *fire risk cost* (FRC) that is equal to the objective probability of the occurrence of the bad state associated with a loss, - $1-\rho$ -, multiplied by the monetary amount at risk, thus:

$$CRI = (1-\rho) \times x_V \quad (1).$$

In summary, the definition of the *risk of fire* therefore interlinks with the occurrence of a dangerous situation within the scope of this implying the existence of damages and/or losses (*danger*) of a known probability. The probability of the occurrence of this dangerous situation depends on a set of circumstances and associated with a specific risk (*risk*) – losses and/or

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[3] We base our definition on that by Cool (2002).

[4] The generic definition of risk refers to the various states of occurrences or contingent states and not only to two. However, while in our case, it only makes sense to consider just two cases: either the forest burns –contingent state 1 or the bad state; or the forest does not burn – contingent state 2 or the good state. Therefore, the definition of risk gets formulated more specifically according to these two contingent states and the respective results associated with each one.

damage. The scale of these losses and damages (hence, the scale of the risk) depends on the risk factors (*hazard*).

In the literature on fires, there is no clear definition of the concept of *fire risk*. We encounter different notions of *danger*, *hazard*, or *risk*, which get indistinctly applied to designate the same phenomenon or, furthermore, serving as equal signifiers but applied in different contexts (Bachmann 1999). This confusion of concepts has hindered the comparison of results produced by diverse studies on the subject and, subsequently, hindering advances in the methodologies for the management of fire risks.

San-Miguel-Ayanz (2002) recognises this conceptual confusion before clarifying how, in the literature on fires, there are various types of concept for *risk* that get applied dependent on whether these relate to: 1) either the probability of fire breaking out; 2) or the probability of a fire having started; 3) or the combined probability of the occurrences of ignition and a fire starting; 4) or, still furthermore, the probability of a fire breaking out plus the damage and/or losses associated with this occurrence. Critically analysing these four concepts, San-Miguel-Ayanz (2002) and Vayda (2006) conclude how some studies prove more complete and wide reaching than others; in this perspective, all of their conclusions may serve for later studies of *risk* and the management of forest fire risks just so long as the scope of application of each study is appropriate to its respective object. To this end, they highlight, for example, that the expression *start of a forest fire* – understands "forest fire" as an uncontrollable fire on a large scale (*wildfire*) – and is not equivalent to the term *ignition*, to the extent that not all ignitions or outbreaks result in forest fires. According to these same authors, there can only be reference to a *forest fire* when there is an *ignition* and, subsequently, in keeping with the presence of specific factors relating to the spread and propagation of the flames – the existence of *combustibles* and *climate conditions* – that which provide the origins enabling the fire to spread and grow (thus, at the beginning of the fire). After all, the probability of the occurrences of forest fires on a large scale very much depends on the stock of combustible materials in the forest and the respective level of combustion (which favours the advance of the fire to a greater or lesser extent) and a set of other external causes, anthropogenic and natural, that are to determine the number of ignitions and the extent the fires spread. Indeed, it is this same set of factors that one section of the literature on fire risks designates as *hazard*.

The definition of forest fire risk associated with the probability of a fire breaking out was that adopted by the FAO[5] - "… the chance of a fire starting as determined by the presence and activity of any causative agent" – and by the DELFI Forum (*Vocabulary of Forest Fire Terms*, http://www.cinar.gr./delfi/) – "… the probability of fire initiation".

[5] FAO. 1986. Wildland Fire Management Terminology. *FAO Forestry Paper M – 99*. ISBN 92 – 5 – 0024207.

The second type of definition refers to the existence of *risk* but solely associated with the number of ignitions. This definition is put into practice by the *Canadian Forest Services* (Canadian Forest Services 1997). However, Vayda (2006) draws attention to the fact that, should the objective be forest fire risk management or the prevention and/or limiting the damage caused by the fires or to act to prevent the destruction of the forestry ecosystems threatened by such blazes, then the definition of fire risk based only on the number of ignitions falls clearly short to the extent that this does not convey the relevant information as regards the risk of fires developing and spreading For fire risk management policies, the most appropriate definition for utilisation would be that which associates *risk* to the *beginnings of fire* and not only with the *risks of ignitions*. Furthermore, in the opinion of Vayda, the usage of the definition of fire risks stemming from the number of ignitions is only appropriate when attempting to define and evaluate measures for preventing/limiting the damage associated with the fires, whenever there are improvements in the studies on ignition within the framework of: *i)* when able to reconstruct the actions that led to the occurrences of ignition in the case of these having been the source of major fires; *ii)* and, based on the conclusions obtained in *i)*, attempting to establish a causal relationship – between the effect of the type of ignition and the development of a specific type of fire. Nevertheless, and very commonly, the sources of ignition differ and are very often of unknown origins and clearly hindering the task of establishing a causal relationship – the deterministic effect between a specific source of ignition and the subsequent forest fire. In such cases, what becomes relevant to fire prevention and/or limiting the resulting damage is less knowledge about the source of ignition but rather grasping the factors that determine the development and spread of the fire, such as the existing combustible load, the level of humidity, the geographic profile, the existence of water sources for firefighting, among other aspects.

The third type of fire risk definition incorporates how the concept always requires defining based upon its two integral components, thus *risk of ignition* and *risk of fire*[6].

Finally, the fourth type of fire risk definition stems from that based upon the definition proposed by the *Society for Risk Analysis* that refers to *risk* as holding *the potential for realization of unwanted, adverse consequences to human life, health, property or the environment*. This definition clearly conjugates *risk* (or the potential threat of human exposure to the threat of losses) with the *losses* associated with this risk, that is, equivalent to the definition of risk defined at the beginning of this section and in addition to the definitions of risk defended by Shields and Tolhurst (2003), Bachman (1999) and Bachman and Allgöwer (1998). Bachman (1999) explicitly recognises the importance of clarifying the conceptual framework associated with the risk of fire before contributing through making a comparison between the definitions of the terms *danger*,

[6] Chuvieco, E. and Congalton, R. G. 1989. Application of Remote Sensing and Geographic Information Systems to Forest Fire Hazard Mapping. *Remote Sensing of Environment* **29**: 147 – 159: "… fire risk is the union of the two components: fire hazard and fire ignition".

hazard and *risk* as provided by *Webster's College Dictionary* (1992) and by the FAO[7] (1986) glossaries of the *Canadian Committee on Forest Fire Management* (1987) and the *Ministry of Forests* of the Canadian province of British Columbia (1997)[8]. This reaches the following conclusions:

1. *Danger is an abstract concept of human perception. Danger per se does not exist. It is defined by subjective human and societal perception and assessment factors (of the physical and non – physical environment) that are considered harmful* (*op. cit.* p. 4);
2. *Hazard is a process leading to undesirable outcomes (op. cit,* p. 4);
3. *Risk comprises the probability of an undesired event and the outcome of it. An undesired event is a realization of a hazard.* (*op. cit.* p. 4).

In conclusion, and faced by this scenario of disorder characterised by: *i)* the absence of any conceptual clarity around the definition of *forest fire risk*; *ii)* the terms *danger, hazard* and *risk* get applied indistinctly to study different situations interrelated with forest fires risks; *iii)* due to *ii)*, the most commonly applied definitions of *risk* in the literature on forest fires derive either from the factors impacting on the number of ignitions; or with the factors impacting on the number of ignitions and the subsequent development of fires; or, and still furthermore, with the consequences in terms of the losses suffered due to the fires, just which of these definition of fire risks need applying by economists? As the evaluation of the economic impact model associated with fire risks and the choice and evaluation of the effects of mechanisms preventing and combatting fires provide the two objects of study of greatest interest to economists, then the fire risk definition that best aligns with attaining these objectives is the initial definition that we presented and that also coincides with that of Shields and Tolhurst (2003) and Bachmann (1999) and according to which the *risk of fire should be associated with the probability of the occurrence of fire and the resulting monetarily quantifiable economic, social and environmental damages and losses*.

3. Evaluating the cost of fire risks

In the section above, we defined the cost of fires as representing an uncertain value – the *fire risk cost* FRC, defined analytically by equation *(1)* -, that depends on the probability of fires breaking out; their dimensions; and the monetary losses and damage resulting. In order to forecast and estimate FRC, we first need to identify the probability of a fire occurring - $(1 - \rho)$ - and the monetary amount at risk of getting consumed or damaged in any way by the fire – x_V -.

For the calculation of the monetary value at risk x_V, this should only consider the losses and damages deemed *relevant*, thus, only those identified as having effectively occurred and only if the fire breaks out, spreads and propagates. The total value threatened by the incidence – the fire

[7] FAO. 1986. *Wildfire Management Terminology*. Forest Resources Development Branch. FAO: Rome.
[8] Ministry of Forests. 1997. *Glossary of Forestry Terms*. Ministry of Forests: British Columbia.

- refers to the monetary value of all of the damages and economic, environmental and social losses directly associated with this fire evaluated according to the perspective of the interests of society.

3.1 Probability of Fires Occurring

The level of probability of the occurrence of fires within a specific period of time, in a specific location and under certain circumstances - $(1 - \rho)$ - , depends on three factors:

i) the existence of ignitions;

ii) the existence of the conditions necessary to the fire propagating;

iii) the existing means of preventing and combatting, and their respective productivity.

A fire may only ever take place when these three essential factors are present: the existence of stocks of combustibles, available in sufficient quantity and quality to feed the fire; the existence of a source of heat, human or otherwise – humans; and the existence of oxygen. With oxygen not playing any relevant role in the case of forest fires, the same does not apply to the remaining factors. The probability of the occurrence of *ignitions* (the *causes of fires*) may stem whether from human causes (accidental or criminal) or from natural causes, even with the former holding the greatest importance, especially in areas of interface between forests and human activities. That is precisely the case with Portugal: 98.8% of fires are of human origin, of which 35.4% are caused intentionally, 27.4% have undetermined causes and 26.8% arise from causes interrelated with negligent practices (DGRF 2006). However, it is difficult to model all human activities in either spatial or temporal terms in order to be able to establish a sufficiently deterministic cause/effect relationship between the aforementioned activities and the fires that would then enable an estimation of the probability of human caused ignitions. The cause/effect relationship between human activities and the outbreak of forest fires depends on countless variables that range from the type of planning for human activities in the respective geographic area through to the type of settlement, the type of economic activities, the size of the population, the perceptions of these populations as regards the risk of forest fires and the interrelated personal and social consequences, the means of access, the existence of specific infrastructure types, etcetera.

The probability of the conditions for the fire to spread existing stems directly from the quantity of combustible materials existing locally and with their greater or lesser propensity to burning following the respective ignition phase. There are two types of parameters associated with the classification of combustible materials able to influence the probability of a fire spreading: 1) the structure of the combustible material and its incidence across the terrain – the coverage; 2) the level of humidity of the combustible materials[9]. Finally, the development of a fire in spatial terms and the fluctuations in its levels of intensity shall equally depend on the efficiency of the

[9] Silva y, F. R. 1998. Local Evaluation of the Forest Fires Risk Through Danger Indices. Application to the Forest Regions of Andaluzia, *in Proceedings of the III International Conference on Forest Fire Research*, 14th Conference on Fire and Forest Meteorology, Vol. 1, 1071 – 1084: Coimbra.

preventive and firefighting measures adopted. In turn, the effectiveness of these measures for prevention and combat also depend on the topographic characteristics of the terrain, the availability of water supply points, the quality and accuracy of the data in possession of the Fire Fighting and Prevention Services, etcetera.

The probability of the occurrence of fires, or their risk, is susceptible to expression in diverse, different ways with greater or lesser degrees of complexity. One of the simpler forms of doing so consists of applying the percentage average of forest burned per year over a determined period of time (Riera and Mogas 2004). The more complex forms involve elaborating more sophisticated risk indicators. In the majority of cases, such indicators calculate the probability of incidence of fires for a specific temporal period and for each respective region and thereby allowing for the geographic identification of areas experiencing greater exposure to fire risks. Their production requires the identification of two sets of variables: the first set contains the variables that shape the probability of such occurrences and the second contains the variables for characterising and quantifying the contribution of each one of the explanatory variables for the probability of the occurrence of fires. These variables are subsequently correlated with a dependent variable - the *index* (San – Miguel – Ayanz 2002) – that quantifies the risk of fire. In the literature on the forest fire risk calculation methodologies, different methods serve for the building of these indices. These different methodologies[10] vary with: *i)* the technique utilised; *ii)* the explanatory variables and the dependent variable applied for the quantification of the level of risk which in turn depends on the definition of forest fire risk under consideration; *iii)* the level of temporal variability in the explanatory variables.

One of the methodologies susceptible to application for classifying the various already proposed indices stems from the temporal scale applied to the variability in the variables contained. According to this classification methodology, we may distinguish between *short term indices* and *long term indices*. The *short term indices,* or *dynamic indices*, vary continuously over very short temporal frames. These indices indicate the fire risk based upon analysis of the minimum level of humidity in the prevailing vegetation, thus in the combustible materials, below which the probability of fires spreading begins rising (*vegetation water stress*, San – Miguel – Ayanz, (2002): p. 3). However, diverse difficulties of a technical nature render it difficult and where not impossible to determine the water content present in the vegetation. And, whenever this happens, the common practice involves adopting another type of variable that holds the particularity of influencing the level of humidity in the vegetation, as is the case with meteorological variables, which are easier to identify and quantify. The great variability that characterises these short term indices render them of little value to the formulation of structural policies for the efficient and effective prevention/combat of major forest fires. Hence, it makes greater sense to apply the long

[10] See Chuvieco et al. (1999), *supra cit*., for a description of the most common methodologies for calculating these fire risk indices.

term indices for the quantification of fire risks (San – Miguel – Ayanz 2002). As such, we henceforth make no further reference to the short term category detailed above.

In the case of the long term indices, as the name indeed conveys, these incorporate explanatory variables that either vary little over the short term (as is the case with the socioeconomic, demographic variables, etcetera) or are practically static (as in the case of the topography, for example) (see Figure 5). The objective here involves detecting what are the stable conditions that most favour the occurrence of fires, defining the geographic areas where there is the greatest likelihood of forest fires due to the intrinsic characteristics prevailing. These indices have proven particularly useful to the process of defining alternative and more efficient and effective strategies for preventing and combatting forest fires to the extent that they reveal those areas exposed to the highest risks and where, as such, the priorities include the installation of fixed infrastructures for combatting and preventing fires while also raising the incidence of surveillance and fire-spotting activities. Nevertheless, to the best of our knowledge, the long term indices thus far estimated and calculated (for example, by Mercer and Prestemon 2005; Pereira and Santos 2003; Shields and Tolhurst 2003; the indices established under the auspices of the Natural Hazard Project of the EC DG Joint Research Center, 1999; Bachmann and Allgöwer 1998; Chuvieco and Congalton 1998; Jain *et al* 1996) do not consider the third factor of the occurrence of fires over a specific period of time, the specific location and the circumstances prevailing there: thus the means of prevention/combat for fires and their respective operational deployment. Indeed, we only found a reference to such factors in the work by Shields and Tolhurst (2003) in which these authors present the definition of fire risk as first suggested by Fournier d'Albe[1] and expressed in the equation below:

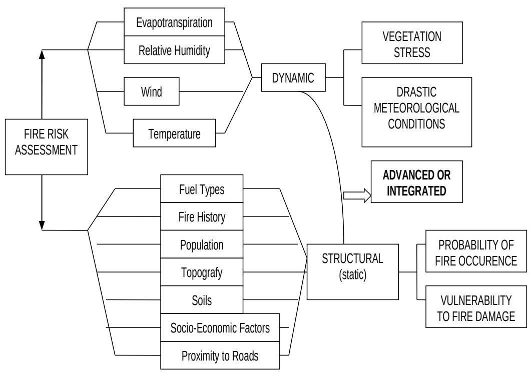

Figura 5 Methodologies Used in the Computation of the Forest Fire Risk Indices (*in* San-Miguel-Ayanz 2002, p. 4)

$$Risk = \frac{probability \times loss}{level\ of\ intervention}$$

The long term index that most closely resembles the fire risk definition adopted for this study is that from the *Integrated Long Term Index* proposed by the *Natural Hazard Project of the EC* research group as this integrates the two risk components that would seem of greatest relevance, hence, the probability of occurrence and the potential losses.

3.2 Monetary Costs Associated with Losses

The second FRC component encapsulates the monetary values at risk of destruction or damage in some way by forest fire. According to Ramachandran (1998) and Weiner (2001), the economic costs associated with fire may be generically classified into three different types: *Economic Costs associated with Direct Damage*; *Economic Costs associated with Indirect or Subsequent Damage*; and *National Economic Costs*.

The *Economic Costs associated with Direct Damage* are those resulting from the direct damage and losses that occur during the fire burning phase alongside those of its combatting and extinguishing and interrelated with: property (forests, buildings infrastructures); the reduction in the social wellbeing associated with the disappearance of recreational, education and research use values, the option and the almost-option and the legacy; the direct damage to human life – deaths and/or injuries directly caused by the fire - ; the direct damage to the surrounding environment – loss of biodiversity, alterations to water drainage and run-off patterns and the quality of subsequent water capture, the worsening of soil erosion and desertification related phenomena, the rise in greenhouse gas emissions, the reduction in the natural capacity of the forest to regeneration, etcetera -.

The *Economic Costs associated with Indirect or Subsequent Damage* encapsulate the losses that occur for some time after the extinguishing of the fire and may be of two types: *indirect costs associated with damage to the life of individuals* and *indirect or subsequent costs associated with material damage*. The *first type* includes the psychological and financial damage incurred by families, dependents of individual victims of the fire, whether fatal or otherwise, and that may emerge in the episodes of stress suffered by the owners, their respective families and employees or motivated by the financial losses experienced by the owners. The *second type* – the indirect or subsequent costs -, encapsulates the damage to agriculture-animal breeding, industrial and commercial establishments in terms of the loss of revenues and profits, posts of employment, production, exports and, also spanning the import of goods that would never have happened were the fire not to have taken place. Only a proportion of these costs has, in practice, been subject to estimation and set down in monetary values. The remainder have never been: either because there is no reliable statistical information in order to achieve this; and/or because they require the utilisation of complex statistical and econometric techniques. Such is the case with evaluating the costs interrelated with losses to the services produced by forestry ecosystems; the losses of intangible cultural benefits or those associated with legacy values; or the costs arising from the emotional suffering and the impact on the prevailing standard of health of both the population and the firefighting teams; those costs due to the disturbances to the wellbeing of communities; and as well as those costs triggered by the economic distortions caused by the fires[11]. In addition to the technical difficulties in calculation, the nature of some indirect or subsequent costs underpin the forecast that their contribution towards the total losses on the national scale would only be minor and significantly below the contribution made by the direct costs (Ramachandran 1998): hence, the sum of the indirect losses and the indirect gains caused by the fires at the national scale may result in a lower contribution than predicted, and substantially below the contribution made by direct damage. For example, the United Kingdom, for 1993, estimated direct fire related losses as amounting to £800 million while the indirect losses totalled £90 million[12].

Finally, the *National Economic Costs* include those incurred by the Fire Service, irrespective of their legal status as Volunteer, Municipality, Forestry or Private brigades; the costs of administration incurred by insurance companies with fire insurance policies; the costs of preventing and fighting fires and those incurred by the government in activities such as regulating fire protection, prevention and combat activities (Weiner 2001). Not all *National Economic Costs* have been subject to estimation, especially those interrelated with the costs of researching into fire security and prevention, the costs incurred with private fire brigades and those resulting from traffic accidents taking place during the firefighting phase.

Adding up all of these aforementioned cost inputs results in an estimate for the *Total Fire Cost*. Nevertheless, in practice, the inputs serving for the definition and quantification of the *Total Fire Cost* may vary (Ramachandran 1998), *i)* either according to the personal opinion that the actor holds about that susceptible to consideration as a fire associated costs; *ii)* or according to the usage and final purpose of this type of estimate. Indeed, given that the range of actors affected by forest fires is so very large, incorporating private landowners, business owners and entrepreneurs, the fire service, local government, the central state, insurance firms, companies producing firefighting and prevention equipment, and the population in general, it is understandable that the methodologies applied to the economic evaluation of forest fire costs and, more specifically, the nature of the individual cost inputs for consideration in this estimate vary substantially according to the perspectives of the parties interested in the quantification of the monetary value of these costs[13] (for further detail on this issue, please see Ramachandran 1998). For example, the owners of timber producing forests may only consider the losses stemming from burned and/or damaged timber as relevant while the non-property owning population may include other categories of economic, social and environmental losses and damage beyond the timber itself, such as the loss of legacy values or the loss of recreational or landscape values, for example. Therefore, whenever

[11] Please see Ramachandran (1998) for further details about the quantification studies on the subsequent costs of fires.
[12] Wilmot, T. 1996. *United Nations Fire Statistics Study*. World Fire Statistics Centre Bulletin 12, Geneva Association: Geneva.
[13] Bachmann and Allgöwer (1998) refer explicitly to how there are two perspectives on risk: the subjective and the collective. The subjective describes risk from the perspective of the individual (the acceptor of risk) who may be affected to various extents, across different scenarios. The collective describes the perspective of risk in relation to a scenario – risk donor – that impacts on, with differing degrees of intensity, a varying number of risk acceptors.

seeking to quantify the costs associated with uncertain forest fire related events so as to improve their risk management by the central government authorities, then the relevant economic costs due for consideration are those that are marginally incurred by society; thus, those costs that only take place when there is a specific fire. Within this perspective, consideration needs paying only to the following *relevant costs of forest fires from the national perspective* (of society):

- the direct costs related with the destruction or damage of built and natural capital, both public and private;
- the costs resulting both from fighting forest fires and from extinguishing operations;
- the costs with reforesting and/or the recovery of destroyed ecosystems;
- the social costs stemming from stress, injuries and deaths among the surrounding populations and firefighting crews;
- and the costs arising out of the emissions of greenhouse gas emissions caused by the fire.

Falling beyond the scope of consideration as relevant forest fire costs at the national level are all of those associated with fire prevention, the administrative costs of insurance companies and as well as the broader costs of the fire service to the extent that this type of cost would always have to be paid by society irrespective of whether or not there are forest fires[14]. This also does not include the loss of business and profits, drops in the outputs of productive activities directly or indirectly dependent on the forest and forest product exports or the rise in imports to counter the shortfall in forest produce production as among the indirect costs of fires.

3.3 Methodology for estimating the costs associated with losses

The economic, social and environmental costs of major forest fires are difficult to calculate because they are so variable, spatially extensive and susceptible to emerging over long temporal periods and very commonly highly difficult to either identify or to value. Some of these costs are easier to quantify monetarily because they encapsulate the loss of market traded goods and services. Immediately, the physical loss/damage of these goods and services is easily subject to quantification through estimating the loss of the respective consumers and producer profits in the respective markets; alternatively, they may always be valued in accordance with the respective market price as a *proxy* for the evaluation of the value lost. However, there are many other losses across the social, cultural and environmental dimensions that are not related with market traded goods and services and, therefore, it is not possible to apply direct market values to make their respective evaluations. In these cases, the evaluation becomes technically more complex and complicated but does still remain feasible.

[14] In economic theory, these costs are sunk costs. Sunk costs are never considered when seeking to evaluate the costs/benefits associated with any occurrence in particular.

The easier to identify and monetarily value losses/damages are those arising from the destruction of capital built by man, whether publicly or privately owned, which includes buildings, machinery, infrastructures, vehicles; those stemming from expenditure on combatting and extinguishing the fires, reforesting and regenerating the ecosystems; and the costs from the loss of wood and vegetal materials. All other damage inherently contains greater difficulties in terms of accurate quantification and estimation, especially due to not having been directly valued monetarily. Such is the case with the loss of value of properties, the downturn in revenues stemming from economic activities impacted by the fires, the damage associated with stress, healthcare problems and the loss of human lives, the loss of ecological functions generated by the forestry ecosystems such as, and for example, the supply and/or purification of water or the control of soil erosion, costs related to damage to the landscape, the loss of biodiversity, climate change and so forth. Due to the sheer diversity in costs, economists need to deploy different methods to estimate them in monetary terms.

3.3.1 Damage Associated with Losses of Natural Capital: the Value of Forests

The main direct damage caused by forest fires is clearly the destruction of the forest ecosystems and the loss of the goods and natural services that they produced prior to the fire.

Ecological Economics, the scientific field that emerged in the late 1980s, enabled forests to evolve from a view encapsulating them merely as a stock of planted timber in order to become interpreted as an ecosystem or a system of natural production, whose productive processes generate natural products (goods and services) in the form of stocks or flows, which are appropriated and consumed by society in general and by economic actors in particular, whether directly or indirectly in order to satisfy the general wellbeing. The existence of healthy and sustainable ecosystems provides society with the sustainable production and maintenance not only of the stock of planted timber but also a diversified range of other ecological goods and services[15].

According to economists, the value of forests represents a subjective value interrelated with variations in the level of individual utility brought about by qualitative/quantitative alterations in the forest between these two self-defined, different states or scenarios. This economic value[16] stems from the flow of benefits[17] that the economic actors (state, consumers and producers) appropriate in the form of surpluses (of the consumer and the producer), when applying, for whatever the different purpose, the goods and services produced free of any charge by forest ecosystems. The measure most commonly used in the monetary quantification of these surpluses is the marginal willingness to pay (*MWP* hereafter) for the benefits or the marginal willingness to

[15] This definition of the goods and services produced by forests adopts the nomenclature proposed by the FAO (FAO 2004. Global Forest Resources Assessment Update 2005. Terms and Definitions. *Working Paper 83/E*, Forest Department, FAO: Rome.

[16] For further consideration of the concept of the total economic value of a natural resource, see Mendes, I. 2006. Valuing Ecosystems. A Methodological Applying Approach. *The ICFAI Journal of Environmental Economics, Vol IV***(2)***: p. 7-34*.

[17] A benefit might equally be a benefit directly related with the enjoyment of a good or service produced by a forest or a loss (and its respective costs) avoided.

receive (*MWR* hereafter)[18] a monetary quantity in place of the benefits, amounts that, in both cases, are expressed by the economic actors either in a direct fashion, that is, through the observation of market prices in the case of natural products subject to transactions or, otherwise in an indirect fashion, thus either applying the markets for other tradeable products that bear some relationship with the natural products subject to the respective value estimation, or, alternatively, simply by asking individuals what is their willingness to pay to be able to continue to benefit from the existence and usage of natural products.

The ecological wealth dimension of forestry ecosystems – here understood as represented by the variety and quality of the natural goods and services provided -, depending on the type of forest according to their origins and composition. In the specific case of Portuguese forests with their Mediterranean characteristics, the main goods and services produced include (Merlo and Briales 2000, adapted):

i) Wood products: timber for the paper pulp and for the wood manufacturing industries; wood for burning and charcoal production; wood for handicrafts;

ii) Non-wood products – cork, resin, mushrooms and truffles, dried and fresh wild fruits, acorns, water, honey and beeswax, plants, animals, etcetera: including products destined for human foodstuffs and animal feed; products acting as raw materials in the production of medicinal, perfumery and cosmetics products, colourings, utensils and handicrafts, tourism and leisure; research and education; and goods of other types (including publications and films promoting forestry ecosystems);

iii) Production of biomass: production of biomass above ground level (stems, stumps, branches, bark, seeds and leaves); production of subterranean biomass (living roots); and the production of dead biomass (including all the dead biomass above or below the soil with the exception of that due to remain and decompose in the soil);

iv) Services provided such as ecological functions including: the protection of hydrographic basins and soil erosion control; the regulation of floods and microclimates; the purification and retention of water and nutrients; the production of fertile soils, carbon capture[19]; the sustainable maintenance of biodiversity, that is, the number, variety and variability of living organisms existing in the forest and, also, the production and maintenance of landscapes.

Society applies these forestry goods and functions (hereafter designated simply as products) for the most varied of purposes, which generate benefits that reflect in improvements to the social

[18] It was Mäler who defined four measures of value for non-market tradeable goods and services based upon economic measurements of their traditional values: these were redefined in accordance with the variations in the quantities and/or qualities of natural capital rather than variations in prices as happens in the case of measurements of value for tradeable goods (Mäler KG. 1971. A Method of Estimating Social Benefits from Pollution Control. *Swedish Journal of Economics* **73**: 121-133; Mäler KG. 1974. *Environmental Economics: a Theoretical Inquiry*. Johns Hopkins University Press: Baltimore).

[19] The forests capture carbon across three levels: in the living biomass above the soils (in the stems, stumps, branches, bark, seeds and leaves); in the living biomass below the soil (relating to the living roots); and in the dead biomass (including all dead biomass whether above or below the soil level).

wellbeing and utility, and that may be monetarily evaluated as a type of social, consumer and producer surplus.

The ways in which economic actors deploy these forestry goods and services establish the foundations for the definition of the nomenclature of the total value of forestry ecosystems with the scope for the definition of three types of environmental value (Pearce *et al* 1989): the Direct Use Value, the Indirect Use Value and the Non-use Value. Figure 6 schematically summarises the nomenclature applied for the description of the economic Total Value concept for Forests (Total Forest Value, *TFV*). The *TFV* is defined as equal to the sum of the inputs that constitute the Use Value (*UV*) and the Non-use Value (*NUV*):

$$TFV = UV + NUV = (DUV + IUV + OP) + (EV + LV)$$

The *DUV* (Direct Use Value) includes all the benefits directly related with the usage that families, companies and the state make of forestry products, whether directly appropriated via transactions in their own markets or via revenues. The products may serve for final consumption products for households generating the benefits associated with this consumption; or as factors for productive processes whether for economic activities (primary, secondary and tertiary sectors) or for the households themselves (for example, in the self-production of recreational, leisure, cultural or educational services) – in this case, the products are considered as a natural capital component.

The *IUV* (Indirect Use Value) refers to all of the benefits received indirectly by economic actors, managed in accordance with how these in fact benefit their ecological support functions

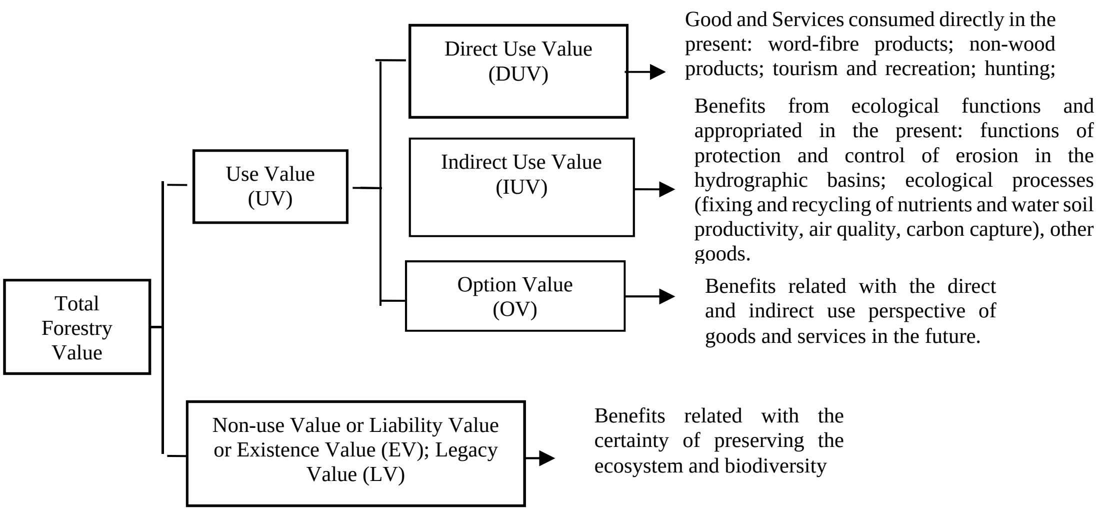

Figure 6 Total Forest Economic Value

and the protection freely provided by the performance of forestry ecosystems. *IUV* is directly quantifiable through the markets. For example, a forest ecosystem generates indirect use value in keeping with how it controls and limits the damage caused by soil erosion and floodwaters, thereby protecting agricultural and fishing activities and the existence of pure water. Some forests are also responsible for maintaining microclimates that produce beneficial collateral effects for agricultural productivity and the quality of life of populations. Another important indirect effect arises from the carbon capture function and the contribution made towards reducing the greenhouse gas emissions that drive climate change.

The *OV* (Option Value) refers to the benefits associated with guaranteeing the preservation of the forest ecosystems for future usage by society whether directly and/or indirectly; the OV thus reflects an insurance premium that actors are prepared to pay today in order to ensure the existence of the forest and the maintenance of its biodiversity and the respective ecological functions into the future.

Some authors also point to the existence of an Almost Option Value (*AOV*) that derives from the uncertainties and lack of current knowledge about the ecosystems and their functioning. Some individuals fear that, should forest ecosystems be used in the present for economic purposes, then there is the risk of losing goods and services of great potential value and that are currently unknown. The *AOV* refers to the social benefits associated with the preservation of ecosystems for motives relating to precaution and the hope that scientific advances in the future might return more information on their utility.

The *EV* (Existence Value) approaches the social benefits interlinking with the satisfaction perceived by some individuals who are not associated with any type of current or optional usage of forest ecosystems but only with the satisfaction stemming from the certainty that these ecosystems are preserved and thus may continue to thrive only because they deem that these ecosystems have to exist.. This type of intangible value is closely interconnected with factors of a social, altruistic or religious order that shape individual decisions to such an extent that these persons are willing to pay a monetary value to maintain this certainty that there are the conditions in effect to guarantee the survival of biodiversity, the wild species and their habitats. This type of value is generally more apparent and relevant to individuals that either do not live close to the ecosystems or that do not directly use the goods and services that they produce or, furthermore, who benefit only very marginally from their indirect usage.

Finally, the *LV* (Legacy Value) reflects the benefits associated with the preservation of the forest for the enjoyment and utilisation of future generations.

The characteristics of the benefits provided by the forest ecosystems also extend to their spatial zones of differentiated influences in accordance with the type of benefit considered and the public character, to a greater or lesser extent, of the respective environmental product. For example, the benefits associated with the direct usage of timber products or the direct usage of non-timber products, principally impacts on the country hosting the forest and, as such, may assume characteristics of a private nature and subject to direct transactions in markets. Furthermore, there is another set of goods and services supplied by the forests with its benefits reaching beyond local and regional borders and, in some cases, international boundaries. Services provided in protecting and regulating the hydrographic basins that reach beyond local, regional and council borders, for example, belong to this group in accordance with the scale of the respective basin. Due to such characteristics, there are difficulties in attributing property rights to this type of services and excluding individuals from their benefit; furthermore, their consumption by one individual does not affect their consumption by a second individual. As such, this type of service incorporates features that are characteristic of pure public goods. There are also others that take on global levels of importance as is the case with the carbon capture function and the preservation of biodiversity that, by their very nature, are clearly pure public goods. Within this framework, the forest values or benefits that we have just described may also be classified into three other categories based on geographic criteria for their level of influence and their public or private nature and correspondingly distinguishing between on-site private benefits, on-site public benefits and global benefits.

Clearly, not all forests produce the same benefits and services and, as such, not all are able to provide the benefits described above. For example, the natural and semi-natural forests (FAO 2004), containing indigenous species that spread with and without human intervention, produce ecosystems that are richer from the biodiversity perspective and correspondingly hold indirect values with the existence of expressive economic values. At the other extreme, there are the forests planted exclusively for the production of timber, especially the monocultures, that produce lower levels of biodiversity than their natural counterparts. The richness of forest ecosystems and the economic values that they provide depend on the arboreal composition and the percentage of indigenous species that make up the ecosystem: for example, an industrial eucalyptus plantation generates a direct use value probably higher than its indirect value due to the timber produced for paper pulp and with only a very low level, where not entirely absent, of existence value. However, in the case of a cork oak forest, the values from direct and indirect uses and its existence may return far more balanced values.

Another factor requiring consideration within the scope of *TFV* calculations encapsulates its secondary nature and its level of maturity in the temporal period which the respective calculation spans. An ecosystem that is undergoing a period of recovery following the occurrence of a fire, whether or not involving human intervention, does not produce the same quantity and quality of natural goods and services that were in production prior to the blaze.

Economically, the *TFV* represents a subjective value and interrelates with the variations in the utility levels of individuals caused by a qualitative/quantitative alteration in the forest and the benefits this provides with these two world states needing clear definition. The economic value relates to the variation in the flows of benefits that economic actors (the state, consumers and producers) appropriate in the form of surpluses when using the goods and services produced pro bono by forest ecosystems for whatever the purpose.

The two world states define distinctive scenarios for that being subjected to valuation. When what is at stake is the total value of an ecosystem that produces flows of goods and services over the course of a certain period of time, then the world state scenarios taken into account are: *i)* the current world state of the forest ecosystem and its respective goods and services; and *ii)* the second world state characterised by the destruction of the forest ecosystem and the subsequent loss of the goods and services provided in the first world state. *Figure 7* graphically portrays the concept of value associated with the existence of an ecosystem and the aforementioned two world states.

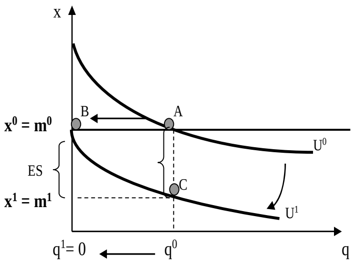

Figure 7 Equivalent Surplus for the ecosystem change from the initial state to the final state q^1 , where $q^1 = 0$.

In this figure, *q* represents the quantity and quality of the natural products provided by the forest ecosystem undergoing valuation; q^0 represents the current state of the natural products under production there; q^1 represents the final state following the occurrence of fire – assuming that the fire shall destroy both the ecosystem and the flow of forestry goods and services it produces and hence $q^1 = 0$; *A* represents the bundle consumed by a representative individual prior to the fire, composed of q^0 quantities of goods and services supplied by the ecosystem and x^0 quantities of other market goods and services on which individuals integrally spend m^0 of their income so as to maximise their utility. U^0 is the level of wellbeing or the utility that the individual has to consume bundle *A*: whenever a fire occurs, this supposes that the ecosystem gets destroyed and the individual correspondingly loses the benefit to enjoy the forestry goods and services previously produced and hence the representative individual is then forced to consume a new bundle, bundle *B*, should there have been no alterations in their initial levels of income. The new bundle B provides individuals with a lower level of wellbeing to that prevailing prior to the forest fire with the utility level dropping from U^0 to U^1. To the extent that the value an individual attributes to the ecosystems is equal to the monetary amount theoretically designated the Equivalent Surplus (*ES*) that the individual is prepared to pay when consuming *A* in order to avoid the destruction of the ecosystem. Whenever consuming *A* and benefitting from the utility level of U^0, the individual prefers to see the utility decline to U^1 through means of a reduction in earnings from m^0 to m^1 (with $m^1 = m^0 - ES$), rather than suffering a reduction in utility due to the destruction of the ecosystem and therefore willing to pay the *ES* amount. This is the most common measure used in the quantification of the monetary value of goods non-tradeable in markets and referred to as the Marginal Willingness to Pay Equivalent (MWP^E). This therefore constitutes the measurement applied for the quantification of the different proportions making the respective types of value contained in the *TFV* and refers to the monetary quantity that each individual is willing to pay to ensure their right to being able to consume the currently existing forestry goods and/or services and avoid the fall in their wellbeing and utility brought about by the destruction of the ecosystem and its benefits due to the consequences of forest fires.

When we refer to economic market products, *MWP* becomes the most effective approach to quantifying the value that individuals attribute to the consumption of additional product units. Estimations of value derive from calculations of consumer or producer surpluses in accordance with the curves expressing their intentions as regards the supply and demand for tradeable products across various levels of market prices (Baumol and Oates 1988). However, the application to quantify the value of the inputs making up the *TFV* raises problems simply because not all forestry goods and services are market tradeable with only some of the range eligible for direct market trading. In their case, their marginal value may be directly observed through the respective transaction price. Within this group is the majority of forestry products associated with its direct usage and includes, for example, timber-fibre and other forestry products, with the exception of benefits of usage related to leisure, education or research. Subsequently, there is another group of benefits related with the usage of forest products that are not directly traded in their own markets but with a value that may be indirectly observed. This group includes, for example, the benefits related with the utilisation of forestry ecosystems for recreational purposes or the benefits accruing from the ecological outputs and functions of the respective ecosystems. These ecological services may not be directly traded on markets because they display the characteristics of public goods, thus, are neither rivals nor mutually exclusive[20]. The *willingness to pay* for this type of goods and services requires estimating indirectly, applying as the *proxy* the expenditure incurred by individuals in the consumption of other goods and services directly market tradeable and that are complementary or replacements for forestry goods and services. In these cases, expressed preference based methods incorporating these substitute or complementary markets are applied. There is also a third group of forest products with benefits that cannot be observed through markets either directly or indirectly, as is the case of the non-use benefits. However, the non-existence of any type of market information about these products does not mean that their value cannot be estimated. In order to achieve this, the methods applied are able to ascertain the *willingness to pay,* questioning individuals directly to this end: these methods are

[20] The Goods considered Public or Collective Consumer Goods are those that hold the following properties: a) non – exclusion: property according to which once it has been provided, it is no longer possible to exclude the actor who does not pay for their consumption; b) non – rivalry or non – exhaustion: a property meaning that over consumption by any particular user does not incur additional costs, thus, the consumption costs of a marginal user are null or bordering on zero. The goods displaying both of these two characteristics are pure public goods and it is not possible to charge prices for their usage; hence, they also have no market.

designated expressed preference based methods and are those most commonly applied to estimate the non-use benefits. There is also a fourth type of valuation method entitled dose-response methods or those methods based on functions of production that attempt to establish a direct relationship between the level of wellbeing measured by the increases in the production of other market goods and services directly or indirectly related with forestry resources and the quantitative or qualitative variations experienced by this forestry resource (Mäler 1992).

Table 1 classifies the benefits according to the types of usage that economic actors make of the forestry goods and services and the type of relationship, direct or indirect, that they maintain with market prices. The non-existence of markets for such a great range of forestry benefits ensures that private producers and forestry managers in general lack the motivation to include them in their decision making processes except whenever otherwise explicitly required to. Similarly, public agencies are led to systematically underestimate the importance of this type of benefit to society across the local, regional, national and even global levels as they are less visible than the earnings, profits, taxes and jobs generated by the products with direct uses such as the timber, the landscape (when serving for tourism activities), or hunting. This remains the case even when the

Table 1 Forestry Goods and Services, Type of Benefits and Market Relationship

FOREST PRODUCTS	TYPE OF USE	TYPE OF VALUE	USERS	RIVALRY	EXCLUSION	MARKET VALUE
Wood	Input (I), Direct Consumption (CD)	DUV	Mostly Companies (E);	R(Rival)	Excludable (E)	Direct (D)
Landscape/forest ecosystem	Tourism (T), Recreation and Leisure (RL), Education and Research	DUV	E; Families(F)	+/- NR(Non-Rival)	+/-Non-Excludable (NE)	D ; Indirect (IN)
Flora/Biomass	I;RL;CD; Support Services (SS)	DUV	E; F;	R; NR	E, NE	D ; IN
Fauna	I; RL ;CD; SS;T	DUV	E; F;	R; NR	E,NE	D ; IN
Regulating Hydrographic Basins	SS	IUV	E; F;	NR	NE	IN
Water	I;RL;SS;CD	IUV + DUV	E; F;	R,NR	E, NE	IN
Soil protection	SS;	IUV	E; F;	NR	NE	IN
Local climate	SS;	IUV	E; F;	NR	NE	IN
Carbon capture	SS	IUV	E; F;	NR	NE	D
Humus production	SS; I;CD	IUV	E; F;	R, NR	E, NE	IN
Option Value	Use option transferred to the future	OV	E; F;	NR	NE	Without Market (SM)
Non-Use Value	Intangible use	NUV	F	NR	NE	(SM)

forestry benefits are in part, tradeable or informally tradeable and leaving their worth and value relatively understated. For example, local populations gather and sell non-timber products such as mushrooms, dried fruits and wild fruits as well as plants for subsequent sale even while the income generated by such taxable activities generally gets either ignored or underestimated at the national level even while of great importance to the wealth prevailing in local communities. Similarly, the usage of forest ecosystems for recreational purposes takes place free of any charge that also reflects an under evaluation of the true *willingness to pay* f or visitors as regards the right to use these ecosystems and their products of benefit to recreational and leisure activities.

When forest fires break out, a substantial number of hectares of forest ecosystems burns and society loses the goods and forest functions hitherto in production. This loss may be economically quantified as equal to the total value of the forest destroyed. The stock and the flows of timber and non-timber products decrease drastically thus making the quantity and quality of forest services available become far lower with a corresponding fall in the benefits provided, which, in turn, impacts on the variations in the wellbeing over the short and long terms. The short term consequences directly relate with the damage to the wood-fibre materials available to local communities, which may result in imbalances in the respective markets due to excessive inflows of damaged timber. This sudden peak in wood based materials represents a temporary and sharp drop in the market price (whenever there is no government intervention to counter such effects) and in the drop in earnings to landowners. In the long term, the market impacts may include the reduction in the supply both of timber and other non-timber products available, which may drive a rise in prices in the respective markets and generate significant increases in earnings for those forest owners that escape the effects of the fire. However, this rise in prices may be met by recourse to imports. Both the short term effects on the markets for timber and non-timber products and the long term effects may not however cause major impacts whenever governments adopt economic policies that counter or moderate the effects of these types of consequences. Whenever the case, it makes no sense to account for the effects of forest fires on markets as losses.

In addition to the fall in the long run supply of timber and non-timber products, there is also the loss of ecological functions previously met by the natural ecosystem, which requires society incur additional costs due to the need to invest in built technologies able to replace those that were formerly natural and performed by the forest free of any charge prior to its destruction by fire.

The social costs of fires associated with the loss of forest ecosystems therefore also prove equal to the sum of the use benefits (direct and indirect) and of non-use that society is no longer able to access in addition to the loss of the existence benefits: thus, the total costs of the fires also has to include the total value of the ecosystems destroyed by the actions of the fires.

3.3.2 Damage Associated with Economic Activity and Property Losses

In generic terms, the economic aspects of the damage caused by the fires that break out in close proximity to urban settlements might be fairly easy to evaluate monetarily. Nevertheless, their identification and classification as relevant losses due to the occurrence of forest fires nevertheless constitutes a task that still involves a great deal of ambiguity. The economic damage includes the effects of fire on the local economies reflected in the destruction of their economic activities and the subsequent decline in the wealth created and the contributions made in the form of taxation coupled with the loss of employment and wage reductions.

The identification problems that we refer to above stem from how the cause of these effects may not be the fire but rather the actual dynamics prevailing in the local economy. For example, a company that was on the verge of shutting down when experiencing a forest fire should not receive the same valuation as a company with a flourishing business. In the concrete case of the damage caused to public and private properties, there are also issues in undertaking a monetary evaluation of the losses similarly related to identification problems. For example, when buildings burn, there is the need to identify whether or not these are covered by insurance because only these enter within the framework of losses from the social perspective.

In order to overcome the problems interrelated with the difficulties of identifying the losses considered relevant, inventories are needed to clearly list the economic activities existing immediately before and immediately after the fire and that detail those properties with and without insurance that were subject to fire damage. In the majority of cases, in practice, these inventories either do not exist or of restricted access and even when existing are often incomplete. In any of these cases, the evaluation process for this type of loss is rendered inviable: in practice, these losses should only be subject to consideration whenever having reliable data.

3.3.3 Social Damage from Greenhouse Gas Emissions

In addition to the stress and other psychological disturbances caused by major disasters, forest fires produce smoke and fumes containing high concentrations of pollutants such as soot, carbon monoxide, and carbon dioxide among other greenhouse gases. These emissions depend on the intensity of the blaze and the specific atmospheric conditions prevailing and may result in significantly negative effects not only for the local populations but also those living in areas further away from the region affected. In accordance with various studies made on this subject[21], these negative effects range from respiratory effects with the occurrence of internal lesions to the lungs that hold the potential to turn into chronic respiratory diseases.

Establishing an inventory and monetary quantification for this type of cost incurs difficulties and hence generally not considered by the majority of even the scarce studies that do quantify forest fire losses caused except for those that caused major regional catastrophes, such as the huge forest fires in Indonesia in 1997. In those studies making such estimates, these stem from calculations based upon inventorying the number of cases related to respiratory diseases taking place in the region affected by the fires and that made recourse to hospitals or medical appointments. The costs were later estimated in accordance with the monetary costs incurred with the subsequent treatment in addition to the cost of losing days of work due to the need for treatment.

The evaluation of the costs arising from greenhouse gas emissions involves inventorying the quantities of such gases produced by the fires and the carbon prices prevailing in the licensed carbon trading markets or, alternatively, evaluating the equivalent costs of investment society would have to incur in order to deploy carbon capture technology of sufficient capacity to cope with the additional gases emitted by the fires, such as capturing gas and storing it beneath ground, for example.

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[21] See, for example, Frakenberg, E., McKee, D. and Thomas, D. 2002. Health Consequences of Forest Fires in Indonesia. http://www.iussp.org/Bangkok2002/S0PFrankenberg.pdf, quoted by Riera 2005.

3.3.4 The Costs of Fighting Fires and of Regenerating Forestry Ecosystems

The costs met by society in combatting forest fires also include all of the marginal costs caused by blazes through the phases of fighting, extinguishing and regenerating the ecosystem. This here includes the expenditure on the equipment required in directly tackling forest fires (vehicles, planes, helicopters, etcetera); additional human resources; tools and materials consumed or damaged during the firefighting; the administrative costs involved in deploying teams for firefighting and emergency evacuation operations, the removal of destroyed materials and all of the other fire extinguishing costs. In turn, the expenses incurred in regenerating the forestry ecosystems extend to those associated with protecting tree roots, the placing of barriers to contain the effects of soil erosion, and the planting of new trees, for example.

4. Examples from the literature of monetary estimates of the costs of fighting forest fires

Of the four forest fire cost components detailed in the sub-sections above, those stemming from the destruction of ecosystems and the resulting loss of value raises the greatest difficulties for calculation. In order to estimate *TFV*, we need to estimate the monetary value of the three components of this value: *UV*, *IUV* and *NUV*, thus, estimating these as a whole and simultaneously. All of the methods applied in the monetary quantification of forestry benefits that form integral components of *TFV*, whether or not tradeable in markets, are based on calculations of individual willingness to pay for these forestry benefits, thus, on estimates of the monetary expression of preferences held by consumers and producers of the different forestry goods and services.

The value components relating to directly market tradeable benefits are easily estimated based upon the respective market prices as detailed above. In order to calculate the monetary value of non-tradeable benefits, economists (for example Freeman 2003; and Hufschmidt *et al* 1983, among others) have theoretically and empirically developed – especially from the 1990s onwards – diverse methods and techniques for such valuations. Table 2 indicates those most commonly deployed for the valuation of various types of forestry ecosystem benefits before Table 3 summarises the techniques applied for the valuation of the most relevant forestry benefits and the advantages and disadvantages of each one. Such examples of TFV quantification include Matero and Saastamoinen (2007), Merlo and Croitoru (2005), Beukering (2003), Guo *et al* (2001), Mohd-Shahwahid and McNally (2001), Xue and Tisdell (2001),Glover and Jessup (1999), Andersen (1997), Adger *et al* (1994), Peters *et al* (1989), for example.

Across these studies, both the benefits and the valuation techniques applied in calculating *UV*, *IUV* and *NUV* vary substantially in accordance with the description of the benefit under valuation and its relationship with markets and hence the estimated values and any putative comparisons among them, should be interpreted carefully.

Table 2 Methodologies and Technique Used in Valuing *TFV* Components

Forestry Products	Type of Value	Market Value	Valuation Methodology	Most Used Valuation Techniques
Wood	UV	Direct (D)	Direct Method	Market prices for wood products
Landscape/forest ecosystem	UV	D ; Indirect(IN)	Direct Method; Indirect Method; Expressed Preferences	Prices paid for tourism activities; Travel Cost; CVM[(a)]
Flora/Biomass	UV	D ; IN	Market Prices; Indirect Method	Market prices for tradeable goods; Costs Avoided; Indirect Markets
Fauna	UV	D ; IN	Direct Method; Indirect Method	Market Prices; Travel Cost; CVM
Regulating Hydrographic Basins	IUV	IN	Indirect Method; Functions of Production Based Methods	Costs avoided; Production Function
Water	IUV + UV	D; IN	Direct Method; Indirect Method	Market Prices for Water; Costs avoided
Soil protection	IUV	IN	Functions of Production Based Methods; Indirect Method	Costs avoided; Production Function
Local climate	IUV	IN	Functions of Production Based Methods	Production Function
Carbon capture	IUV	D	Market Prices	Carbon market price
Humus production	IUV	IN	Indirect Method	Costs avoided
Option Value	OV	Without Market (SM)	Expressed Preferences	CVM
Non-Use Value	NUV	(SM)	Expressed Preferences	CVM

(a) CVM = Contingency Valuation Method;

Table 3 Valuation Methods by Type of Benefit

Valuation Method	Relevant Forestry Benefits	Advantages and Disadvantages
Direct Market Prices: already existing sources provide the statistical data; with the values corrected by seasonal variations, transport costs and public policy distortions.	The most commonly used method for valuing forestry products, whether timber or others, whether only partially or informally traded; enabling the valuation of the benefits of subsistence consumption and/or informal consumption.	Theoretically, this is the best valuable method as this reflects the preferences (user benefits). However, this still requires adjustments to correct public policy distortions and market failures. However, when able to ascertain the demand-price elasticity for products, we may make secure extrapolations about their future value.
Substitute Markets: ➢ CVM: applies travel and accommodation costs as proxies for the natural product value; data obtained by questionnaire. ➢ Hedonic Prices Method (HPM): uses statistical methods to correlate the variations in the market prices of a good with alterations in quantity/quality of an environmental good related to the former. ➢ Substitute Goods: takes the prices of substitute goods on the market to value the benefits of the environmental products that have no markets.	CVM serves to estimate the demand for the forestry in terms of the recreational services consumed by individuals and calculate the respective use benefit. Hedonic Prices are able to estimate the proximity benefit of areas of forest on the value of the residential and/or commercial properties – thus, estimating the value of the landscape and the natural amenities. Substitute Goods are frequently used whenever there are approximate substitute markets for forestry products other than wood/timber.	As they are based on market values, even when indirect, these methods are deemed reliable. However, the relationship between the environmental benefit and the substitute market must be technically well expressed and quantified. CVM is the most common method and in widespread usage even while technically and statistically demanding. The HPM is technically complicated and extremely demanding in terms of data.
Function of Production: Method based on alterations in the productive outputs related to an environmental product: this establishes a physical relationship between variations in the quality/quantity of an environmental product and the quality/quantity of a market product.	These methods serve to estimate the effects of alterations in land usage, for example due to the effects of timber felling on hunting, the climate or recreational usages.	This method requires extremely clear and complete statistics on the biophysical relationships. Of all methods, this is the most interdisciplinary approach.
Expressed Preferences: CVM: applies questionnaires to ascertain either the willingness of individuals to pay for positive variations in an environmental benefit or the likelihood of accepting compensation for damage suffered.	This method underpins the quantification of forest TV and NUV. This is currently recognised as the most appropriate means for quantifying non-use values and its validity has received judicial recognition in the United States.	CVM gains widespread acceptance whenever certain and specific norms are complied with in its application.
Avoided Costs Based Methods: The costs of restoration, maintenance or replacement measures for goods and services naturally produced by forests act as proxies for the values of environmental products.	This serves for quantifying any forestry benefit: this also includes analysis of the opportunity cost.	These are the most secure methods. However, under certain temporal, and financial circumstances and depending on data availability, may be the only applicable means.

Dixon *et al* (1994) demonstrate how market prices are susceptible to utilisation for the purposes of valuing environmental impacts. The empirical studies focusing on calculating the *UV* of forestry products also include those already referred to in this section. However, there are others that only evaluate *UV* – either in its totality or only the *UV* of the timber produced -, but not the *TFV*: this is the case, for example, with Peters *et al* (1989). Empirical studies evaluating carbon capture services, for example, include all of the aforementioned studies and, furthermore, those of Boyland (2006) and Ramirez *et al* (2002) who only estimate the benefits of this type of ecological service. Empirical examples for the evaluation of recreational benefits include for example, and in addition to those already referred to for *TFV*, Mendes and Proença (2011); Martínez-Espiñeira *et al* (2008); Scarpa *et al* (2000) (only the contingency evaluation method); Zawacki *et al* (2000), Bellú *et al* (1997) and Perna (1994). Núñez *et al* (2006), Loomis *et al* (2003), and Xue and Tisdell (2001) all deploy indirect methods based on market prices. Further to all of the studies listed above, Abildtrup and Strange (1999) provide another example of an estimate of the option value in the specific case of services provided by forested hydrographic basins as regards water purification.

5. Conclusion

There is a trend towards a rising number of major forest fires occurring in Portugal. The financial and human resources deployed in their combat have proven not only insufficient but also a major drain on state coffers. The violence of the major blazes that have broken out in the meanwhile, the losses and damage inflicted on society and the difficulties experienced in putting them out, all warn public actors and society in general to invest deeper in the application of the principle of precaution according to which prevention policies require prioritising over firefighting. So that these prevention (above all) and firefighting policies achieve efficiency and cost effectiveness, there is a need to be able to forecast and determine the risk associated with these fires and the respective monetary value of the losses caused. In order to determine this risk and proceed with the respective monetary evaluation, we need to ascertain the two components of this risk: the probability of a fire occurring and its intensity; and the monetary value of the losses and damages caused. The objective of this working paper stems directly from contributing towards this subject through a methodological approach.

Accordingly, there are two clear and immediate conclusions. In order to calculate the fire risk and forecast the respective damage, we need to know the probability of such occurrences – which includes the probability both of ignition and of the fire developing and spreading in keeping with the orographic and climate restrictions and the existing means of combatting fires and their organisational deployment – and in addition to providing a monetary evaluation of the damages and losses resulting. Evaluating forest fire risks is neither an easy nor a linear task. This process requires approaching through multidisciplinary teams including economists, forestry engineers, environmental engineers, geographers, among others, that deploy equally multidisciplinary theories and technical forecasting models.

There are various obstacles to calculating the monetary value of forest fire risks. The first appears immediately in the definition of the concept of cost due to its random nature: in the literature on forest fires, the concepts of risk and danger are deployed indifferently and generating conceptual confusion. Then, after having chosen and defined the concept of risk that best suits the respectively prevailing purposes, we encounter two new obstacles: how to estimate the likelihood of fires occurring and the value of the losses and damage. In order to estimate the probability of fires occurring, there are various methods: the easiest consists of applying, very simply, the percentage of the area burned in the past; the most complex, but also of much greater relevance to forecasting and management policies, involves recourse to long term indices of fire risks. In order to estimate the losses and damage and estimate the FRC, we should proceed by: 1) choosing only the losses and damage of relevance from society's perspective when planning to apply this type of information to forest fire prevention and firefighting management policies; 2) verifying just which losses may be estimated directly and indirectly through markets, and which are susceptible to calculation in accordance with market values; 3) choosing the methods and techniques appropriate to estimating the monetary values defined in 2).

Within the framework of avoiding some of these difficulties, for putative future evaluation exercises we would propose evaluating the cost of fire risks for forest fire prevention and management policies and incorporating the following different stages:

1) Applying the fire risk concept defined as equal to the product of the probability of fires breaking out and the value of the losses and damage;

2) Estimates of the likelihood of fires require the application of long term risk indices drafted by scientific fields other than economics; should such data not be available, then we might adopt as a *proxy* the percentage of the area that burned in previous years; however, this methodology is not the most appropriate to forecasting and designing different scenarios for the spread of fires and their respective intensities;

3) The calculations of losses and damage should only take into consideration relevant aspects, those directly related to the fire – thus, those that economists designate as *marginal costs of the fire* – costs associated with the destruction and/or damage to forest ecosystems and the subsequent destruction/damage to ecological outputs, whether in the form of timber and non-timber products or in terms of the ecological functions, the option value or the existence value; the costs associated with the marginal expenditure on firefighting in addition to the subsequent costs with extinguishing the fire, reforesting the area and restoring destroyed and damaged ecosystems; and as well as the costs stemming from greenhouse gas emissions;

4) Choosing the most appropriate methods and techniques for estimating the different cost components irrespective of whether or not there is direct market based information.

Calculating the cost of forest fire risks by region constitutes an essential step in achieving the objectives of forest fire prevention projects that should not target the elimination of such risks but rather their management. Indeed, managing risk means reducing it while simultaneously lowering the monetary losses caused by fires.

In the present context of major budgetary restraints, there is a greater need to define efficient risk prevention policies, thus, both cheaper and more effective, which involves answering the following three questions:

i) What are the regions exposed to the greatest risk of forest fire and what is the value of such risks?

ii) What level of forest fire risk is compatible with optimal economic outcomes?

iii) What is the cheapest and most effective fire prevention and fighting strategy to attain this optimal level of risk?

Estimating forest fire risks according to the methodology discussed throughout this chapter is therefore the common denominator to the answers to these three questions.

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ANNEX

Table 1A Number of forest fires in the five southern EU states (1980-2009)

Year	PORTUGAL	SPAIN	FRANCE	ITALY	GREECE	TOTAL
1980	2 349	7 190	5 040	11 963	1 207	27 749
1981	6 730	10 878	5 173	14 503	1 159	38 443
1982	3 626	6 545	5 308	9 557	1 045	26 081
1983	4 539	4 791	4 659	7 956	968	22 913
1984	7 356	7 203	5 672	8 482	1 284	29 997
1985	8 441	12 238	6 249	18 664	1 442	47 034
1986	5 036	7 570	4 353	9 398	1 082	27 439
1987	7 705	8 679	3 043	11 972	1 266	32 665
1988	6 131	9 247	2 837	13 588	1 898	33 701
1989	21 896	20 811	6 763	9 669	1 284	60 423
1990	10 745	12 913	5 881	14 477	1 322	45 338
1991	14 327	13 531	3 888	11 965	858	44 569
1992	14 954	15 955	4 002	14 641	2 582	52 134
1993	16 101	14 254	4 769	14 412	2 406	51 942
1994	19 983	19 263	4 618	11 588	1 763	57 215
1995	34 116	25 827	6 563	7 378	1 438	75 322
1996	28 626	16 771	6 401	9 093	1 508	62 399
1997	23 497	22 320	8 005	11 612	2 273	67 707
1998	34 676	22 446	6 289	9 540	1 842	74 793
1999	25 477	18 237	4 960	6 932	1 486	57 092
2000	34 109	24 118	4 603	8 595	2 581	74 006
2001	26 533	19 547	4 309	7 134	2 535	60 058
2002	26 488	19 929	4 097	4 601	1 141	56 256
2003	26 195	18 616	7 023	9 697	1 452	62 983
2004	21 870	21 394	3 775	6 428	1 748	55 215
2005	35 697	25 492	4 698	7 951	1 544	75 382
2006	19 929	16 355	4 608	5 634	1 417	47 943
2007	18 722	10 915	3 364	10 639	1 983	45 623
2008	13 832	11 612	2 781	6 486	1 481	36 192
2009	26 119	15 391	4 800	5 422	1 063*	52 795
% of total in 2009	49%	29%	9%	10%	2%	100%
Average 1980-1989	7 381	9 515	4 910	11 575	1 264	34 645
Average 1990-1999	22 250	18 152	5 538	11 164	1 748	58 851
Average 2000-2009	24 949	18 337	4 951	7 259	1 695	56 645
Average 1980-2009	18 194	15 335	4 951	9 999	1 569	50 047
TOTAL	545 805	452 848	148 531	299 977	47 058	1 501 409

Source: JRC 2009

Table 2A Area consumed by forest fire in the five southern EU states (1980-2009)

Year	PORTUGAL	SPAIN	FRANCE	ITALY	GREECE	TOTAL
1980	44 251	263 017	22 176	143 919	32 965	506 328
1981	89 798	298 288	27 711	229 850	81 417	727 064
1982	39 556	152 903	55 145	130 456	27 372	405 432
1983	47 811	108 100	53 729	212 678	19 613	441 931
1984	52 710	165 119	27 202	75 272	33 655	353 958
1985	146 254	484 476	57 368	190 640	105 450	984 188
1986	89 522	264 887	51 860	86 420	24 514	517 203
1987	76 269	146 662	14 108	120 697	46 315	404 051
1988	22 434	137 734	6 701	186 405	110 501	463 775
1989	126 237	426 693	75 566	95 161	42 363	766 020
1990	137 252	203 032	72 625	195 319	38 594	646 822
1991	182 486	260 318	10 130	99 860	13 046	565 840
1992	57 011	105 277	16 593	105 692	71 410	355 983
1993	49 963	89 267	16 698	203 749	54 049	413 726
1994	77 323	437 635	24 995	136 334	57 908	734 195
1995	169 612	143 484	18 137	48 884	27 202	407 319
1996	88 867	59 814	11 400	57 988	25 310	243 379
1997	30 535	98 503	21 581	111 230	52 373	314 222
1998	158 369	133 643	19 282	155 553	92 901	559 748
1999	70 613	82 217	15 906	71 117	8 289	248 142
2000	159 605	188 586	24 078	114 648	145 033	631 950
2001	111 850	93 297	20 642	76 427	18 221	320 437
2002	124 411	107 464	30 160	40 791	6 013	308 839
2003	425 726	148 172	73 278	91 805	3 517	742 498
2004	129 539	134 193	13 711	60 176	10 267	347 886
2005	338 262	188 697	22 135	47 575	6 437	603 106
2006	75 510	148 827	7 844	39 946	12 661	284 788
2007	31 450	82 048	8 570	227 729	225 734	575 531
2008	17 244	50 321†	6 001	66 329	29 152	158 621
2009	87 416	110 783	17 000	73 355	35 342‡	323 896
% of total in 2009	27%	34%	5%	23%	11%	100%
Average 1980-1989	73 484	244 788	39 157	147 150	52 417	556 995
Average 1990-1999	102 203	161 319	22 735	118 573	44 108	448 938
Average 2000-2009	150 101	125 239	22 342	83 878	49 238	430 798
Average 1980-2009	108 596	177 115	28 078	116 534	48 587	478 910
TOTAL	3 257 886	5 317 457	842 332	3 496 005	1 457 624	14 367 304

Source: JRC 2009

Table 3A No. of occurrences in Portugal and the respective areas destroyed, per year, between 1 January and 30 September 2012

Anos	Ocorrências			Área ardida (ha)		
	Incêndios florestais	Fogachos (Área <1ha)	Total	Povoamentos	Matos	Total
2002	6.500	19.948	26.448	65.131	59.427	124.558
2003	5.175	20.455	25.630	285.864	139.475	425.339
2004	4.407	15.279	19.686	54.697	69.776	124.473
2005	7.538	25.476	33.014	201.512	119.722	321.234
2006	3.433	16.434	19.867	36.271	39.601	75.872
2007	1.662	9.636	11.298	7.141	12.684	19.825
2008	1.949	10.056	12.005	4.615	8.927	13.542
2009	5.353	18.577	23.930	23.302	59.427	82.729
2010	3.572	16.834	20.406	45.676	83.687	129.363
2011	3.102	14.404	17.506	12.842	33.266	46.108
2012	**4.254**	**16.247**	**20.501**	**47.534**	**56.591**	**104.125**
Média 2002-2011	4.269	16.710	20.979	73.705	62.599	136.304

Source: ICNF 2012