Methodological Approach for Assessing the Economic Impact of Forest Fires Using MODIS Remote Sensing Images[1]

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Abstract

Assessing areas affected by forest fires requires comprehensive studies covering a wide range of analyzes. From an economic standpoint, assessing the affected area in monetary terms is crucial. Determining the degree of loss in the value of natural resources, both those of a tangible and intangible nature, enables knowing the residual value remaining after a fire, i.e., it enables determining the "net change in the value of the resources." While the importance of economic analysis in the planning process for different post-fire rehabilitation actions is indisputable, determining the net change in the value of natural resources becomes complex when the size of the affected area makes gathering the information unfeasible, partly because of the costs involved in obtaining the information and partly because of the time that will elapse before the final assessment is available. Once the set of algorithms that allow the initial assessment and the corresponding depreciation of existing resources due to fire impact have been obtained, the assessment can be made immediately with the help of a geographic information system and the corresponding "fire impact depreciation matrix." The ability to incorporate satellite image processing into economic damage assessment allows identifying with greater precision the delimitation of the affected areas based on the "normalized vegetation index."Analysis and interpretation of MODIS images, combined with the energy intensity emitted by the spread of fire, can be integrated into econometric models in order to obtain, in a geo-referenced manner, the economic value per hectare resulting from wildfire damage. This paper details the methodology followed and the results obtained and validated in a series of wildfires that occurred in different geographic areas.

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Introduction

Forest fires are one of the biggest environmental problems (Moyano and Jimenez 2005). Although fire has been used since ancient times in agricultural plowing and pasture creation for the purpose of livestock use (Kenneth, 1962), socio-economic changes have led to an abandonment of traditional uses. This neglect results in a greater accumulation of scrub (Perez 1990, Rodriguez y Silva and Molina 2010), which, along with the accentuation of climate conditions (Piñol and others 1998), has led to an increase in virulence of forest fires, and consequently an increase in fire damage to natural resources and the surrounding environment.

The valuations of natural resources tend to underestimate the real value of the forest (Constanza and others 1997). Unlike traditional economic activity, the forest environment is characterized by the extraordinary relevance of externalities that involve harm or benefits of considerable magnitude to others. From a socioeconomic perspective, it is necessary to express all the natural resources in monetary terms. The assessment of damages caused by forest fires requires the individualized study of each of the resources (tangible and intangible) and their net value change in relation to fire severity and ecosystem resilience (Molina and others 2009).

The recognition and valuation of natural resources is essential for the spatiotemporal planning of preventive work and post-fire restoration (Molina 2008). Incorporating the concept of vulnerability extends the study beyond an economic valuation, integrating two concepts, the value of the resource and fire behavior. The integration of both concepts is done using a matrix of depreciation ratios based on flame intensity, called "depreciation matrix" (Molina and others 2011, Rodriguez y Silva and others 2012).

Numerous studies have shown the potential of remote sensing in the field of forest fires (Chuvieco and others 2005). The incorporation of satellite imagery to the economic evaluation provides, in a novel way, a tool of undoubted interest to accurately identify the area affected by fire. The advantage of using MODIS satellite imagery lies in the availability of virtually real-time information at zero cost. The difference between the value of the vegetation indices before and after flames have passed through the area can be integrated in a geo-referenced manner with the energy intensity emitted by flames, obtaining indirectly the economic losses per unit area (Rodriguez y Silva and others 2009).

The socioeconomic vulnerability model was made by configuring a mathematical algorithm associated with a Geographic Information System (GIS) facilitating the development of spatiotemporal tracking cartography, at both the individual resource level and the integrated ecosystem vulnerability level. The automation of the calculation and management using GIS is being conducted under the project INFOCOPAS (RTA2009-00153-C03-03) funded by the National Institute for Agricultural Research (INIA, for its acronym in Spanish), to achieve in a versatile manner a geo-referenced understanding of the forest system vulnerability to wildfires, at virtually real time.

Methodology

The economic evaluation of the damage caused after the presence of flames (by MODIS images) has been carried out for 5 campaign fires in Andalusia: *Aldeaquemada* (2004), *Minas de Rio Tinto* (2004), *Alajar* (2006), *Cerro Catena* (2009) and *Cerro Vértice* (2011). This fire group provides a wide range of forest ecosystems and damage levels. The economic impact assessment of a large forest fire requires the following phases of analysis and development:

a) Economic valuation of natural resources
b) Spatial identification of different damage levels.
c) Identification of the net value change in the resources
d) Economic valuation of fire damages.

Economic valuation of natural resources

Economic valuation of natural resources must incorporate three types of resources: tangible resources, environmental services and landscape assets. The valuation of tangible resources includes timber and non-timber products. The methodological approach for assessing the impact on the timber resource is based on an algorithm that integrates the assessment tools, including the natural and artificial origin of woodland (Rodriguez y Silva and others 2012). The valuation of non-timber resources is based on expressions of the Assessment Manual of Losses and Environmental Impact Estimation for Forest Fires (Martínez Ruiz 2000). The assessment of the impact on the hunting resource will be performed through the adjustment proposed in Zamora and others 2010.

The valuation of environmental services includes three resources: carbon fixation, erosion control and faunal biodiversity. The assessment of carbon sequestration includes both the amount fixed at the time of the fire and the amount unfixed from that time, and thus requires the volume with bark, aerial biomass and annual increase (Table 1). The quantity of carbon corresponding to dry biomass was estimated at 50%. The erosion control will be expressed in lost economic profit based on the potential amount of ground lost per surface unit. The expression used for the assessment (Table 1) includes an addend in respect to losses incurred during the first rains (bare soil) and a second addend that includes progressive soil losses until recovery of vegetation with similar protection to the one burned (Molina and others 2009). The faunal biodiversity or unique species valuation is completed via the cost of the species recovery program, or if no specific program is available, through the contingent valuation method (Molina 2008).

Spatial identification of the different damage levels

As an example, this paper discusses the methodological implementation for the *Cerro Catena* fire, which destroyed more than 200 hectares, mainly *Pinus pinaster* forest with semi-dense undergrowth dominated by *Rosmarinus officinalis* and *Juniperus oxycedrus*. The topography is steep with a height of 960-1200 meters above sea level, thus favoring the virulent spread of fire. The fire occurred under meteorological influence characterized by a temperature of 26 °C, relative humidity of 16% and a wind speed of 12.5 km/h.

The spatial identification of the different damage levels was performed using MODIS images (Terra and Aqua) for a previous date (September 6) as well as for a post-fire date (September 22). For both dates the images were acquired from the United States Geological Service’s LP DAAC Server (https://lpdaac.usgs.gov/get_data/data_pool), which is administered by NASA. Preparing the images required the transformation of Sinusoidal Datum (original images) to the European Datum 1950 Zone 30N system, making the overlapping of the images with the fire perimeter in vector format.

Table 1*—Mathematical formulations used for economic valuation*

Resource	Formula	Resource status	Source
Timber	$V_{mad} = (1,7*E*B)/(E+0,85*B)$	Mature and immature	Rodríguez y Silva and others2012
	$E = C_0*p\ [i^e + g(i^e -1)] + A*(i^e – 1)$	Immature	
	$E = (C_{0/z}*t\ [i^e + g(i^e -1)] + (C_0/z)*0,5*(i^e - 1)$	Immature	
	$E = [P*V -P_1*V_1] + P*V\ [(i^{(T-e)} - 1)/(i^{(T-e)})]$	Mature	
	$B = [(V*P*1,025^n)/1,04^n]*[1-(1,025/1,04)^e]*[1 + X*h*p]$	Immature	
	$B = V*h*t[R*P + (1 - R)*P_1]$	Mature	
Use of firewood	$V_{leñas} = P_x*R_x*[((1+i)^n - 1)/(i*(1+i)^n]$	Mature	Martínez 2000; Molina and others 2011;

Hunting	$V_{cin} = P_x*R_x*[(1+i)^n - 1)/(i*(1+i)^n] + S$	Hunting reserve	Zamora and others 2010;
Carbonsequestration	$V_{carb} = CF*PM + IF*PM*RC*[((1+i)^{T-e} - 1)/(i*(1+i)^{T-e}]$	Forest stand	Molina 2008;
Erosion control	$V_{eros} = R_1*P_1 + R_2*P_2\ [((1+i)^n - 1)/(i(1+i)^n)]$	-	Molina and others 2009
Faunal Biodiversity; landscape; Leisure and recreation; Non-use	$V_{biod/pai/oci/nouso} = Rx*[((1+i)^n - 1)/(i*(1+i)^n]$	Presence of particular species	Molina 2008

Where "E" is the timber valuation based on the traditional Spanish approach (€/ha.), "B" is the timber assessment adapted from the American model (€/ ha.), "Co" is the cost of replanting a hectare of land (€/ha.), "p" is the percentage of the stand affected by fire, "i" is the annual interest rate, "g" is the annuity depending on the rotation of the species, "A" is the value of one hectare of land without trees (€/ha.), "e" is the estimated age of the stand at the time of the fire, "V" is the timber volume expressed in m^3/ha., "P" is the price of one m^3 of felled wood (€), "n" is the number of years until the hypothetical felling season, "X" is the mortality coefficient dependent on the severity of the flames, "h" is the percentage of the species in the canopy, "z" is the cost reduction of restocking based on the self-healing phenomenon as a function of the rotation, " P_1" is the price of the damaged wood with commercial use (€/m^3), "V_1" is the volume of damaged wood with utilization (m^3/ha.), "Px" is the price per measurement unit of the resource (€), "Rx" is the annual income per surface area, "S" is the breedingstock per surface unit (€), "CF "is the amount of CO_2 trapped at the time of the fire (t/ha),"PM "is the price per fixed ton (€/t)," IF "is the annual increase of CO_2 retained (t/ha.) "RC" is the income generated by fixing a ton of carbon in a year (€), "R_1" is the amount of soil medium lost the first year (t/ha.), "P_1" is the estimated price for a ton (€), "R_2" is the amount of soil medium lost until the recovery of the original cover (t/ha.).

Subsequently, the bands needed for spatial analysis were identified. Both for the Terra and Aqua platforms, the reflectivities of the bands used are located in the spectrum of 620-670nm (red) for band 1, and 841-876nm (near infrared) for band 2. In the case of images with a resolution of 500 meters, the band 7 used ranged from 210-215nm. Geo-referencing and adjusting of the final fire perimeter was performed with ArcGIS© software, keeping a 150-meter tolerance buffer in order to include the effect of the proximity to the burned area. An adjustment in the size of the cells was performed in order to harmonize bands 1.2 and 7 for the calculation of the vegetation indices. To obtain more detail in the graph showing the results, "cells" of 0.0625 ha

(25x25 meters) were defined.

The vegetation indices used were the NDVI, NBR, DNBR and RdNBR. The calculation of these indices based on MODIS requires mid-infrared (band 7) and near infrared (band 2). MODIS band 7 was used for its intrinsic ability to represent fuel moisture. Below are the various indices formulations:

$$\rho_{i,NIR} + \rho_{i,R}$$
$$\rho_{i,WIR} + \rho_{i,NIR}$$

Where $\rho_{i,NIR}$ is the reflectivity of pixel i in the near infrared band and $\rho_{i,R}$ is the reflectivity of the pixel i in the red band.

In both indices the value range oscillates between -1 and 1. The degree of damage of each "cell" was estimated by the differences in the values of vegetation indices, before and after the fire:

$$D\text{-}NDVI = NDVI_{\text{pre-fire}} - NDVI_{\text{post-fire}}$$
$$DNBR = NBR_{\text{pre-fire}} - NBR_{\text{post-fire}}$$

A third indicator was considered for the study, and corresponds to a normalization of the NBR, with the purpose of eliminating the existent correlation between the result of the ratio and the NBR pre-fire value. To do that, the following adjustment was made to the images:

$$RdNBR = \frac{DNBR}{\sqrt{Abs(NBR_{pre-fire}/1000}}$$

Identification of the net value change in the resources

The determination of losses in natural resources, both tangibles and intangibles, requires knowing the remaining resource value, *i.e.* the "net value change in the resources." This concept requires the incorporation of resource depreciation based on the level of fire intensity. The allocation of the depreciation of each resource according to the level of fire intensity is made on the basis of depreciation ratios or percentage levels, given its simplicity and practical applicability.

In the case of the timber resource and firewood use, and under the framework of research projects FIREMAP, SINAMI and INFOCOPAS, circular plots of 10 m radius were taken for different plant types and damage levels in the following fires: *Huetor* (1993), *Aznacollar* (1995), *Estepona* (1995), *Los Barrios*

(1997), *Cazorla* (2001; 2005), *Aldeaquemada* (2004), *Minas de Rio Tinto* (2004), *Alajar* (2006), *Gaucín* (2006), *Obejo* (2007), *Orcera* (2009) and *Cerro Vértice* (2011). For the valuation of hunting resource losses, information from *Monfragüe National Park* was used, as well as from the *Aldeaquemada* and *Minas de Rio Tinto* fires (Zamora *and others*, 2010), in order to have not only a spatial analysis but also a temporal one of the natural recovery of the breeding stock, and consequently, of the annual revenues generated by the resource.

Depreciation levels of carbon fixation resources and erosion control were estimated based on tree mortality and on the consumption level of biomass in *Cerro Catena*, from measurements in burned and unburned trees with similar mensuration characteristics. Economic valuation of erosive damage, or conversion of lost biomass to monetary units, was determined based on the study of the *Obejo* fire (2007), which analyzed the costs associated with the loss of different soil amounts (tons per hectare). In the case of biodiversity, damage assessment is carried out based on the "subrogated value" (recovery and/or conservation programs) of the government or on the value given by the population (CVM). The values obtained for this resource include adjustments based on post-fire costs invested by the responsible authorities, to prevent the escape and migration of species through food supplementation measures, predator elimination and competition reduction (Molina 2008).

The depreciation ratios of landscape assets are very complicated to validate. The above-mentioned research projects estimate depreciation ratios for these goods by the technique of social preferences or by indirect assessment techniques of landscape perception by comparison between pre and post burned land. Landscape use is affected to a greater extent than the leisure and recreational activities. Large forest fires occurred in *Parque Natural Sierras de Cazorla*, *Segura* y *Las Villas* (location where the Cerro Catena fire occurred). They provided a good basis for quantitative approaches to the impact on landscape assets. This indicates that the fire of 2005 resulted in a 40% decline in the number of tourists and the temporary stoppage of numerous business projects for the renovation and expansion of recreational facilities.

Economic valuation of fire damages

The use of Geographic Information Systems (GIS) allows the identification of vegetation typology and its economic value, and the availability of information about fire behavior. The depreciation rate is estimated individually for each resource based on this behavior.The integration of both concepts provides the economic vulnerability of each resource present in the burned area. Economic valuation of damages is the sum of the vulnerabilities of the resources in the burned area.

Results

Economic valuation of natural resources

The analytical results of the *Cerro Catena* fire indicated the non-use resource as the most important (€ 217, 865) (Table 2). Given the natural character of the *Pinus pinaster* stands affected, and their longevity (over 100 years in some stands), the timber resource also reached a high value (€ 194,093.17). The third resource in order of importance was carbon fixation, given the large amount of aerial biomass in the forests affected (€ 69,137.71).

Table 2—*Economic valuation of resources in "Cerro Catena"*

Resource	Valuation(€)	Representativeness (%)
Timber	194.093,17	29,35
Use of firewood	60.771,17	9,19
Hunting	8.704,35	1,32
Carbon fixation	69.137,71	10,45
Erosion control	21.973	3,32
Biodiversity	6.820,79	1,03
Landscape	27.277	4,12
Leisure and Recreation	54.686	8,27
Non-use	217.865	32,94
TOTAL	661.328,19	100

The total value of the forest resources affected by the fire was € 661,328.19, representing in terms of economic impact per surface unit a value of € 3,164.25 / ha. The landscape assets (landscape, leisure and recreation and non-use) accounted for 45.33% of the value of forests affected, followed by tangible resources (timber, use of firewood and hunting) which accounted for 39.85%.

Economic valuation of natural resources

A reconstruction of the fire potential behavior was performed *in situ*, identifying for each pixel the average flame length (directly related to the intensity of the linear advancing front). Four levels of fire intensity were identified (Table 3):

- Damage degree I. Corresponds to a level of fire intensity (NIF) VI or flame length exceeding 12 meters. Very affected area. Continuous crown-fire, highly virulent, and airborne material consumption. The soil has been virtually denuded.

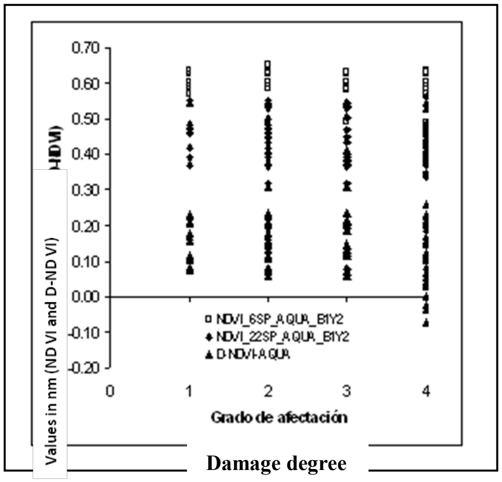
- Damage degree II. Corresponds to a level of fire intensity (NIF) IV or flame length between 6 and 9 meters. Area affected to a moderate extent. Passive crown fire with some crown running. The soil is unprotected by clumps based on the intensity; there is practically a total consumption of superficial fuel.
- Damage degree III. Corresponds to a level of fire intensity (NIF) III or flame length between 3 and 6 m. Moderately affected area. Surface fire with surface material consumption. The fire progresses in accordance to the slope but not downwind. There are isolated torched trees.
- Damage degree IV. Corresponds to a level of fire intensity (NIF) II or flame length between 2 and 3 meters. Slightly affected area. Surface fire with surface material consumption. The fire diminishes, without advantageous slope or wind conditions.

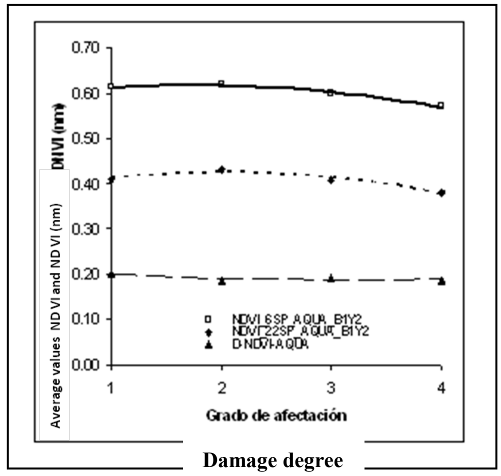
Table 3*—Representation of damage degrees in "Cerro Catena"*

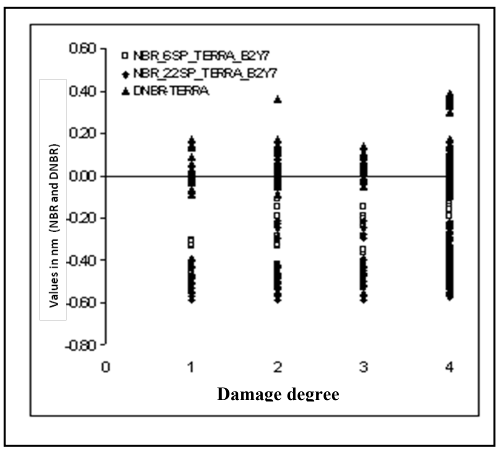
Damage degree	Pixels*	Area (ha.)	Area (%)
I	398	25	12
II	946	59	28
III	356	22	11
IV	1644	103	49

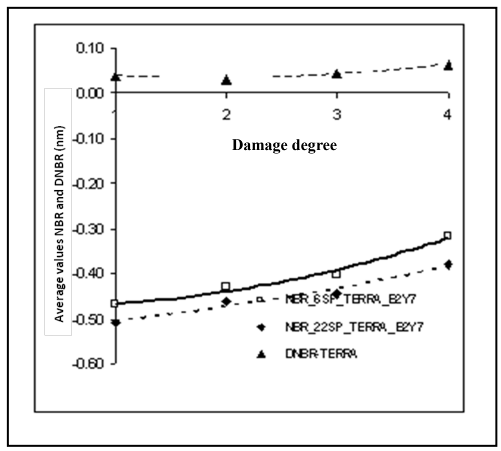
* Cells of 25 x 25 m., defined for all information levels, from resolutions of 250 and 500 m.

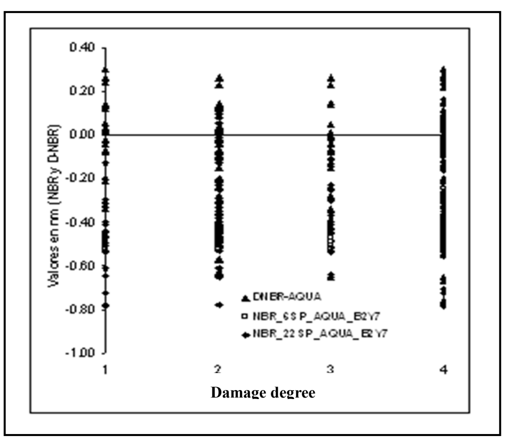
After the analysis, the observed behavior of the indices NDVI, NBR, DNBR, and RdNBR, regarding the identification of the four levels of fire intensity (Figure 1), was heterogeneous. In general, better results were obtained with the NBR compared to those for the NDVI, since it allowed better discrimination and contrast of the post fire severity. The indicator RdNBR allowed eliminating existent correlation between the result of the ratio and the NBRpre-fire value.

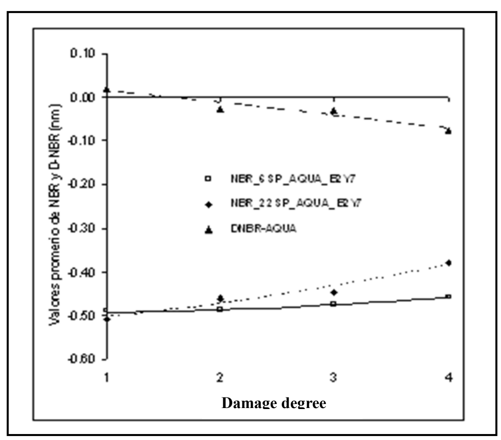

Values in nm (ND VI and D-ND VI)
NDVI_6SP_AQUA_B1Y2
NDVI_22SP_AQUA_B1Y2
D-NDVI-AQUA
Grado de afectación
Damage degree


Average values ND VI and ND VI (nm)
NDVI_6SP_AQUA_B1Y2
NDVI_22SP_AQUA_B1Y2
D-NDVI-AQUA
Grado de afectación
Damage degree


NBR_6SP_TERRA_B2Y7
NBR_22SP_TERRA_B2Y7
DNBR-TERRA
Values in nm (NBR and DNBR)
Damage degree


Average values NBR and DNBR (nm)
Damage degree
NBR_6SP_TERRA_B2Y7
NBR_22SP_TERRA_B2Y7
DNBR-TERRA


Valores en nm (NBR y D-NBR)
DNBR-AQUA
NBR_6SP_AQUA_B2Y7
NBR_22SP_AQUA_B2Y7
Damage degree


Valores promerio de NBR y D-NBR (nm)
NBR_6SP_AQUA_B2Y7
NBR_22SP_AQUA_B2Y7
DNBR-AQUA
Damage degree

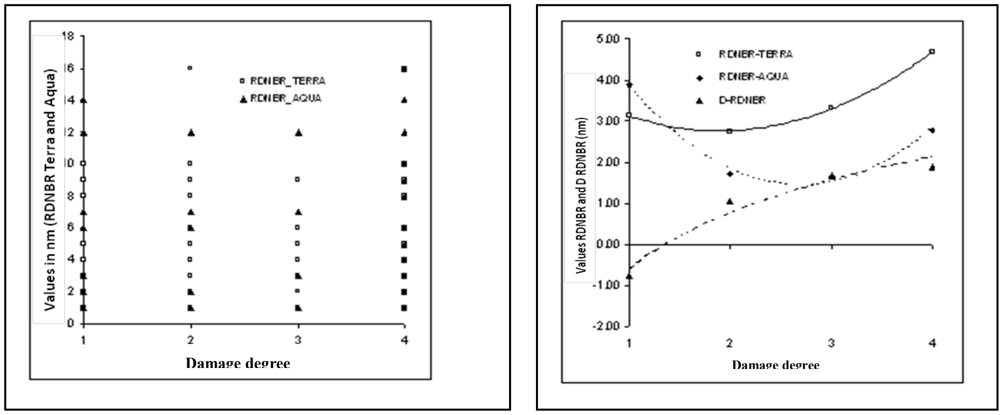


Figure 1—Values of the different indices for September 6 and 22 (left); averages for both measurements (right).

Identification of the net value change in the resources

From the experience gained in large forest fires that occurred in Andalusia during the period 1993-2011 and the scientific results of the research projects FIREMAP, SINAMI and INFOCOPAS, a depreciation matrix was developed (Figure 2).

This matrix was adjusted with the vegetation index of greatest correlation, as in other studies (Rodriguez y Silva and others 2009), in order to find an equation for each resource that provides the depreciation rate such that, applied to the initial socio-economic value, it provides both losses caused by wildfire and the residual economic value of vegetation unaffected by fire. Table 4 shows the models obtained for each resource:

NIF	Vrm	Vrle	Vrci	Vrca	Vrer	Vrbi	Vrpa	Voc	Vrno
I	8,33%	5%	20%	10%	10%	20%	5%	2%	4%
II	16,65%	10%	45%	25%	25%	40%	25%	20%	19%
III	38,58%	20%	65%	45%	45%	60%	60%	55%	46%
IV	57,85%	45%	85%	65%	65%	80%	80%	65%	54%
V	82,79%	65%	95%	85%	85%	100%	90%	85%	69%
VI	89,41%	75%	100%	100%	100%	100%	100%	85%	69%

Figure 2—Depreciation Matrix ("Vrm" timber resource depreciation (*Rodriguez y Silva and others*,2012); "Vrle" firewood use depreciation; "Vrci" hunting resource depreciation; "Vrca" carbon resource depreciation; "Vrer" erosion control depreciation; "Vrbi" faunal biodiversity depreciation; "Vrpa" depreciation of the landscape resource; "Vroc" depreciation of leisure and recreational resource, "Vrno" depreciation of non-use resource).

Table 4*— Correlation models between the rate of depreciation of each resource and RDNBR*

Resource	Model	R^2 (%)
Timber	$y = -11{,}219x^2 - 13{,}105x + 85{,}746$	97,95
Use of firewood	$y = -10{,}178x^2 - 13{,}066x + 69{,}997$	99,81
Hunting	$y = -14{,}244x^2 - 3{,}3187x + 105{,}54$	97,88
Carbon fixing	$y = -10{,}027x^2 - 15{,}545x + 93{,}826$	98,62
Erosion control	$y = -10{,}027x^2 - 15{,}545x + 93{,}826$	98,62
Biodiversity	$y = -13{,}19x^2 - 6{,}3753x + 102{,}61$	98,11
Landscape	$y = -19{,}406x^2 - 3{,}2702x + 108{,}36$	93,39
Leisure and recreation	$y = -14{,}846x^2 - 4{,}1257x + 90{,}027$	87,29
Non-use	$y = -11{,}673x^2 - 2{,}8962x + 73{,}225$	87,43

"y" is the depreciation ratio (%) and "x" the vegetation index value RDNBR

Economic valuation of fire damages

Economic vulnerability in case of the *Monte Catena* fire was high, estimated at € 262,687.99, which corresponds to a unit value in relation to the affected area of € 1,256.88 / ha. Of this amount, the impact of the fire on landscape assets (landscape, leisure, and recreation and non-use) accounted for 45.08% of the total damages caused by the wildfire. Meanwhile, the impact on tangible resources (timber resource, use of firewood and hunting) accounted for only 37.11% of the economic damages.

Table 5*—Economic vulnerability of resources in "Cerro Catena"*

Resource	Valuation (€)	Representativeness (%)
Timber	75.270,43	28,65
Use of firewood	16.788,16	6,39
Hunting	5.427,43	2,07
Carbon fixing	32.679,01	12,44
Erosion control	10.052,00	3,83
Biodiversity	4.042,37	1,54
Landscape	13.792,25	5,25
Leisure and recreation	22.933,50	8,73
Non-use	81.702,84	31,10
TOTAL	262.687,99	100

Discussion

Comprehensive assessments of damages caused by wildfires shed surprising results. Not in vain, the tangible resources represent only a portion of total economic impacts on burned areas (Molina 2008, Molina and others 2009). In case of the "Cerro Catena" fire, its strategic location within a natural park with a large influx of tourists bestows great importance on the landscape assets. Although the forest does not possess leisure and recreational infrastructure, this does not imply ignoring the possibility of future use, that is, it has a non-use value. In this regard and as suggested by other authors (Borchert and others 2003, Velez 2009, Rodriguez y Silva and González-Cabán 2010, Molina and others 2011), the assessment of damages should not pass over the multifunctionality of Mediterranean forests and reduce it to only timber resource losses.

Forest management in the study area has lost yesteryear's primary objective (timber production) and its secondary one (resin production). Its management must be based on multifunctionality, with high emphasis placed on preservation and starting with the use of the landscape. Carbon fixing represents a resource with great potential in the pursuit of economic efficiency. In addition, the occurrence of a wildfire not only means the loss of the fixation capacity of the forests, but also a large amount of emissions. Using vulnerability criterion rather than valuation answers the need for a management tool that incorporates the incidence of the major Mediterranean disturbance, forest fires, in prioritizing actions or creating risk indices (Rodriguez y Silva and others 2009). The classification of currency units in qualitative indices of the potential severity that the impact of a potential fire could cause in an area facilitates connecting or integrating the socioeconomic aspect with other parameters or factors, to the creation of an overall risk and/or danger index (Chuvieco and others 2010).

Identifying the damage level or fire intensity with satellite imagery supported by a field inventory facilitates the extrapolation of the field information to the entire area burned. In this sense, MODIS, due to its free to access download platform,frequency, and effectiveness, is presented as an effective means of support. As other studies have shown (Chuvieco and others 2005), the normalized vegetation index is not presented as the best identifier of the burned area. However, the results achieved via the RdNBR allow obtaining regression equations with high statistical reliability, providing the losses caused by the forest fire based on depreciation ratios (Rodriguez y Silva and others 2009). The differences found in the depreciation ratio of various resources (Molina 2008, Molina and others 2009, 2011; Zamora and others 2010, Rodriguez y Silva and others 2012) determine the need to obtain an equation per resource.

Conclusions

The recognition or valuation of forest ecosystems is essential for spatiotemporal planning conducted by wildfire managers. The importance of having a socioeconomic impact evaluation model addresses a wide range of possibilities, facilitating prevention, evaluation and post-fire restoration work, and consequently, the decision making processes.

The increasing demand for thematic mapping by government agencies with management responsibilities implies the need to develop tools and products based on remote sensing and geographic information systems. Given current economic constraints, the use of a geo-referenced tool with free regular updates (MODIS) allows the inclusion of changes, improvements and temporal or spatial adaptations according to the needs of wildfire managers.

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