Valuation of the Economic Impact of Wildland Fires on Landscape and Recreation Resources: A Proposal to Incorporate them on Damages Valuation[1]

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Abstract

Even when they account for a large part of damages caused by forest fires on environmental and landscape services they are seldom included in the valuation of damage assessments. Some fires within natural parks have caused significantly larger impacts on these environmental and landscape services (nonmarket) than on market services.

The economic valuation of forest fires impacts on environmental and landscape services requires indirect valuation techniques like the travel cost or contingent valuation methods. There are differences on welfare estimates depending on the geographic zone analyzed; In the Natural Park de Aracena y Picos de Arrocho, for example, varying between 25-91 €/visitor. For the same area the recreation and leisure valuation reaches upwards of 21€ million.

The methodological process goes beyond a simple economic valuation because it includes the resources net-value-change depending on fire intensity level. Using an inventory of 14 fires and a survey we developed a resource depreciation net-value-change matrix of environmental services values or depreciation based on fire intensity levels, which is directly related to flame length. Geographic Information Systems (GIS) smooth the integration of fire behavior information and the economic valuation providing a tool for the analysis of the territory economic vulnerability. This allows for the methodological procedure to be used in a prevention mode (through the fire potential behavior) or in a post-fire mode (through a field inventory). With the objective to identify the relative importance of the leisure recreation and landscape services resources within a burned area we provide an economic valuation of fire economic impact for four fires (Obejo, Cerro Vertice, Cerro Catena, and Alhama).

Keywords*:* depreciation rate, socioeconomic vulnerability, travel cost valuation

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Introduction

Occurrence of a forest fire implies economic impacts not only on nonmarket values, but also on landscape and environmental services resources (Kerkviet y Novell 2000). Given its valuation difficulty, these values are generally left out of post-fire expert valuations. However, socioeconomic changes have lead a resurgence in the value of second or recreation homes located in forest areas, mostly on protected natural spaces (Navarrete and González 2003).

Valuation of landscape values requires using indirect methods like travel cost, contingent valuation or hedonic prices (Christie y otros 2006, Lasanta y otros 2006). Use of any of these methodologies create some controversy as they are conditioned by the sample. In this application we will use the travel cost method that uses the consumer's willingness-to-pay as an indicator. Consumer surplus represents the difference between what the consumer is willing to pay for a good or service and the actual amount paid. Considering different cost types imply important differences in the demand curve, and consequently, in consumer's surplus (Azqueta 1996). Travel costs can be divided in two categories, fixed cost (fuel, time, depreciation, etc.) and variable costs (food, lodging, etc.).

The use of Geographic Information Systems (GIS) allows us to measure natural resources values by fire intensity and vegetation class (Zamora et al. 2010, Molina et al. 2009). The georeferenced valuation of natural resource improves not only post-fire economic valuation, but also provides a preventive tool facilitating budget allocation and land management planning (Rodríguez y Silva and González-Cabán 2010). By identifying the location of recreation activities, based on each activity demand, GIS permits the estimation of its economic potential. Therefore, the georeferenced valuation of landscape or recreation services becomes a useful tool for the optimization of prevention activities or damages or impacts mitigation by including resources not generally considered, even though they represent an important component of the ecosystem total value.

The main objective of this work is to propose a methodological procedure for the economic valuation of losses in recreation resources caused by wildfires. This proposal is more than just an economic valuation, because it includes fire behavior components (intensity), and vegetation resiliency, which is a measurement of the landscape vulnerability pre or post fire. As examples, we include preventive applications (Natural Park de Aracena y Picos de Aroche), and post fire application (de Obejo, Cerro Vertice, Cerro Catena, y Alhama fires. We performed an analysis of each zone relative values to test for significant differences between the studied fires.

Materials and Methods

Study Area

In this study we use two scales, one for preventive measures application at landscape level, the other a fire scale for post-fire application. The preventive measure application was used in the Aracena y Picos de Aroche Natural Park in Huelva Province, southwestern Spain (figure 1). The Park total area is a little over 186,000 hectares and changing landscape depending on sun exposure and altitudinal gradient. The rural economy depends on tourism and production of the Iberian swine. The vegetation is dominated by oak species used in an extensive agro-pastoral (dehesa) system, with extensive areas of chestnut trees; also pine plantations, and also scrub zones.

Figure 1- Study area showing fires evaluated and natural park location.

The post-fire application was done for four fire with different vegetation (Figure 1). The Obejo fire affected almost 5,000 hectares, and Cerro Vertice fire almost 150 hectares of private, unsuitable for tourism and lack of infrastructure lands. Though not in a protected area, the Alhama fire (3,260 hectares) was included because it had potential for greater damages due to its location close to urban centers and high presence of hikers and bikers. Finally, the Cerro Catena fire (209 ha) occurred within one of the largest natural spaces in Iberian Peninsula subject to a tourism demand.

Economic valuation: travel cost method

Using the travel cost method (TCM) to value recreation resources requires implementing a survey questionnaire to identify visitors' characteristics and incurred expenses to a recreation area from different zones. The survey questionnaire consisted of three related sections: the first contains information related to basic fixed costs incurred (point of origin, transportation mode, gasoline expenses, etc.), the second contains information on incidental expenses to the trip (lodging and meals costs, etc.), and the last one inquiring about the type of activities performed during the visit and how a fire would affect their visitation to the area.

The demand function can be estimated by individual visitors or by demand zones based on trip point of origin (Haab and McConnel 2002). In our case we used a zone demand model. Consumer surplus was estimated considering the fixed and incidental costs based on four distinct zones: <75 km; 75-150 km; 150-250 km; and >250 km, given the cost differences between the visitors from surrounding towns and those coming from large cities (Figure 2). Transportation costs are estimated based on a mean fuel cost of 1.1 €/liter (mean value for the period 2014-2016) and an average fuel consumption of 11-17 km/liter. In Spain the cost of time is estimated as 8 €/h (Gutiérrez 2008) or 4.85 €/h (Riera et al. 1994). Though the general trend is to use one third of the average wage as the cost of time, more recent studies are suggesting using 50% of the average wage (Wolff 2014). Given that in Spain the average wage is 15.7 €/h (2014), the cost of time would vary from 5.24 €/h y 7.85 €/h whether we use one third or half of the average wage. Because we do not have updated information on the true cost of time in Spain, we chose to use the average of the one third and one half of the average wage or 6.54 €/h.

The mean consumer surplus is then the product of the consumer surplus for each defined zone times its visitation rate from each zone. The annual recreation value is the product of the mean consumer surplus and the number of visitors (from official Natural Spaces visitation statistics and by estimating the direct number of visits or the expert opinion of environmental offices present in the zones). We can also use a proportional apportionment based on the zones landscape qualitative value similar to the proposed by Molina et al. (2016) for the Aracena y Picos de Aroche Natural Park.

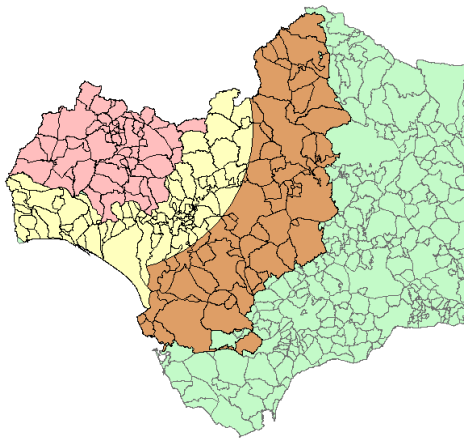

Figure 2-Demand zones identified for the travel cost model valuation of the Aracena y Picos de Aroche Natural Park.

Economic valuation of the fire impact on the recreation resource

To value a fire's economic impact on a zone requires identifying the mean recovery or a resiliency period. Measured as the landscape adaptation and recovery after a fire, the fire intensity and the floristic composition determines an ecosystem resiliency. Therefore, losses are directly proportional to the time of recovery or updating of the economic losses; though there are cases, like areas of pastures without trees where the fire effect can be positive. Damages can be estimated by the following formula:

$$P = V \frac{(1+t)^{n} - 1}{t(1+t)^{n}} \qquad (1)$$

where P are losses in an area completely affected (€/ha), V is the annual value estimated using the travel cost method (€/ha), t is the annual interest rate, and n is the landscape recovery time (in years) to a pre-fire condition. For the study area we use a recovery period between zero (0) years (for pastures without trees and cattle ranching where fire effect is positive) to 70 years for densely populated chestnut tress areas.

As noted, equation 1 estimate the losses for an area completely affected, that is with a maximum flame severity. However, the fire behavior is not homogenous depending on fuels present, topography and weather conditions. Therefore, it is necessary to perform an analysis of the potential fire behavior in the area evaluated using spatial simulators, and a field inventory or satellite imagery for post-fire valuation. The final valuation of the fire's impact is the product of the total valuation and the resource depreciation value, which depends on the flame's intensity (equation

2). Therefore, the proposed tools is more than just economic valuation for it reflects the landscape vulnerability of an ecosystem to fire.

$$I = P * (RD) \quad (2)$$

Where P is defined as before (€/ha), and RD is the resource depreciation rate. The resource depreciation rate is an x amount of one unit of the original landscape depreciation value.

Determining the depreciation rate for a nonmarket resource, such as the use value of an open space, is complicated requiring the use of indirect valuations. For our case we used average depreciation values as a function of the fire intensity that is directly related to flame length (Alexander and Cruz 2012). We determine the values after visiting 14 fires in Andalusia and recreation association's opinion, and the rooms (lodging) demand based on average seasonal occupation rate in relation to the number of pre-fire years.

Results

Economic vulnerability of the recreation resource

A little over 600 in-person interviews were conducted in the valuation of the resource recreation at Aracena y Picos de Aroche Natural Park. After accounting for bad responses, passing by visits, and decline to participate, a total of 500 useable surveys were obtained, for an effective response rate of about 82%; highest response rates were obtained at hotels interviews. The estimated consumer surplus by the four zones identified ranged between 25 and 91 euros. Based on these estimates and a visitation rate of 130,000 annually, the total annual recreation value of the Natural Park ranges between 3.3 and 11.9 million €.

The total recreation value was then proportionally distributed over the landscape based on the zone recreation and tourism infrastructure, and its landscape value (Molina et al. 2016). The two most highly rated activities for the area were hiking and picnicking. As economic theory asserts, the areas closest to the Park provide the greatest visitation rates. We distributed the total recreation value estimate over the landscape by pixels considering the quality of the landscape and the preventive infrastructure. Likewise we assigned an average resiliency period and average fire behavior based on flame length. Using the different fire intensities and social preferences in the 14 fires analyzed we developed a logarithmic function between the depreciation rate (%) and flame length (equation 3).

$$RD = 0.265 \ln(x) + 0.0837 \qquad R^2 = 87 \qquad (3)$$

Where RD is as previously defined and x is the mean flame length in meters.

Using the economic relationships developed in the methodology, and assuming a potential mean fire behavior, the total economic impact of fire on the Arecena y Picos de Aroche Natural Park is between 21 to 76 million €; this is 7 times more than the annual recreation value of the area.

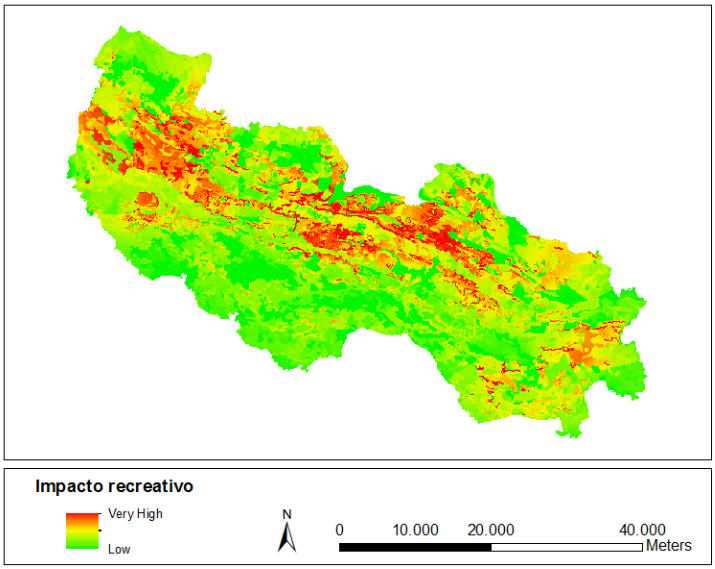

Figure 3- Potential economic impact of qualitative valuation of the recreation use in the Aracena y Picos de Aroche Natural Park.

Economic impact of fire on the recreation resource

As in the previous case, we had to value the recreation resource, using a similar methodology, and an inventory of fire intensity levels to determine the economic impact of fire on the recreation resource. Having collected this information and using a fire severity vegetation map, and all 14 analyzed fires we determine and assign a resiliency period for each vegetation grouping. Because we had georeferenced information for each of the fires were able to prioritize the restoration actions (Figure 4).

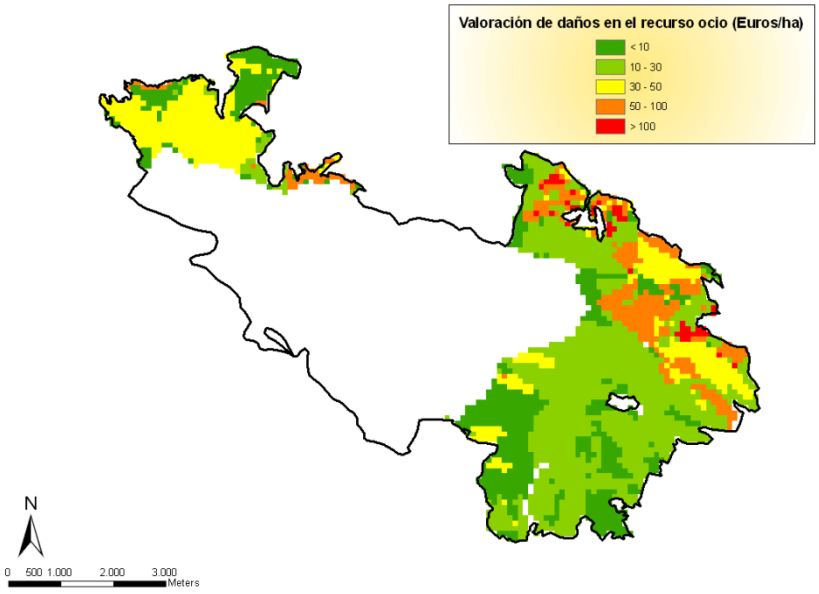

Figure 4- Georeferenced valuation of the economic impact of the Obejo fire on the recreation resources.

Based on the fire burned zones characteristics the economic impact on the recreation resource ranged between 27.78 and 175.72 €/ha (Table 1). In terms of the resource relative importance within the valuation had a range between 3.9 to 13.98%. The importance of the recreation resources close to natural protected areas was the highest at 13.98%, while in places close to urban centers was 11.78%. In the most remote locations the economic impact of fires was 5.31% (±1.99).

Table 1-*Recreation resource valuation for the four fires considered.*

Fire	Mean impact (€/ha)	Relative importance (%)
Obejo	27.78	3.9
Cerro Vertice	36.55	6.72
Alhama	23.75	11.78
Cerro Catena	175.72	13.98

Discussion

Even though the application of TCM to value the economic impact of forest fires has not been applied in Spain, the use of this methodology for recreation resources valuation is an alternative (Riera et al. 1994, Navarrete and González 2003). Not using this tool usually results in an undervaluation of economic impacts from forest fires (Molina et al. 2009). Though the methodology could be subject to criticism because of the sample design and selection we believe, as stated by the United

Nations Food and Agriculture Organization (FAO) (1997): *the economic valuation of natural resources is relevant and useful up to the point that helps managers to make informed decisions. It is possible, even before we have enough information to obtain an exact value, to reform institutions and policies, and stimulate a more sustainable land management, and discourage natural resources depletion.*

Because of the high differences (upward of 8 million euros) in the annual recreation values in the two methodological approaches, it is necessary to caution the need to consider an uncertainty threshold in the valuation of the recreation resources. However, given the importance of tourism for the area's rural development in the study area, we believe necessary incorporation of the incidental costs as a fire could potentially cause the a reduction of the recreation activity itself, even closing the recreation infrastructure analogous to other Andalusian protected spaces (Molina et al. 2009). Although in the short run the recreation vulnerability is high, the recovery periods are not long given the Mediterranean species adaptation to fire and the presence of large swath of lands in the *dehesa* agro-pastoral system (Molina et al. 2011). In this regard, the total recreation vulnerability of the Natural Park is multiply by 7; that is, there is a recovery period of only 7-8 years in the whole Park area.

We included the depreciation rate based on the flame length average value and its direct relationship to fire intensity (Alexander and Cruz 2012) because the simplicity and dynamism required by forest managers making the post-fire valuations. Flame length is the easier parameter to identify in-situ (Zamora et al. 2010) for adjusting the depreciation or damage rate. This equation allows the use of the methodological approach in the preventive mode (determining potential behavior through simulations) and for the post-fire valuation. The methodology application in a preventive mode is a useful tool for landscape scale planning level and budget allocation to mitigate flame caused damages. Its use on valuation of large forest fires can be complemented with satellites imagery (Rodrigues y Silva et al. 2013)

The importance of the recreation resource in the protected natural spaces (Cierra Catena fire) is reflected on the recreation impact analysis of the four fires considered here, as well as in areas around urban centers (Alhama fire). In these two cases its importance is >10% of the total impact, even though there is serious under valuation of damages because they are not normally valued.

Though the relative importance of the recreation resource in the Catena fire does not represent a proportional increase at only 13.98%, the value by unit of area burned of the fire is very high compared to the other fires (175.72 €). This can be due to the importance of the timber resource, carbon dioxide sequestration, and erosion protection in protected natural spaces. In the Alhama fire recreation and leisure represent a high relative importance due in part to the absence of important timber species (no timber values or carbon dioxide sequestration), to the present

infrastructure, and the closeness to urban centers. Finally, in the Cerro Vertice fire the largest resource weight respond to greater number of tree species and their closeness to a national road.

Conclusions

The abandonment of rural areas is due in part to the low economic value of Mediterranean forests; therefore, it is fundamental to perform an integrated valuation of natural resources. Forest fires managers should be responsible for knowing the need to incorporate all fire impacts to the valuation process, especially when they affect directly local communities. Their importance is greater in protected natural spaces or close to urban centers representing more than 10% of all total losses. We should not forget the contribution of preventive mapping to operational capabilities for decision making and budget allocation.

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