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Research article

The economic and environmental impact of fire preventive strategies in the Mediterranean region

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ABSTRACT

Fire behaviour in the Mediterranean region has been altered by climate change. In the last decade, not only has the occurrence of fires increased but also their virulence. This is primarily due to higher temperatures and the decrease in the rainfall, which have made forest ecosystems less able to withstand fires. It has also been observed that most wildfires are related directly or indirectly with human actions, and they usually occur in wildland-urban interface (WUI) areas. The current research focuses on the economic quantification of the benefits that fire preventive strategies could generate, demonstrating that it is worth it to invest in this kind of measures for both the environment and the society. This study shows the results of a pioneering project, called GUARDIAN, which is applied in a WUI area located at the east of Spain, with the aim of preventing and combating wildfires that could put at risk the life of 15,000 inhabitants while preserving the Natural Park of Túria and La Vallesa (Valencia-Spain). GUARDIAN is a multifaceted project that integrates recycled water, advanced technology, and ecological enhancements to create a more fire-resilient environment while educating and preparing the local community for fire-related challenges. The results of the current research intend to give a value to those benefits of the project that usually have not a market value and are difficult to measure, and due to that fact, they are not usually considered in the cost-benefit analysis. The methodology applied allows to compare in economic terms the environmental benefits of fire preventive measures implemented in the GUARDIAN project with the costs incurred by the measures developed. The environmental area protected by the project results in a value that ranges between €338,035,481 to €485,384,281. Accordingly, the methodology and results of this study are of great interest to public administrations, encouraging the implementation of fire preventive strategies.

1. Introduction

The European Mediterranean area, given its climatic and forestry characteristics, is a region vulnerable to forest fires (Sivrikaya and Küçük, 2022). The Mediterranean climate is generally warm and dry with high temperatures during summer period and low rainfall, which means that the typical vegetation is adapted to hot weather and water stress, giving as a result forests of coniferous and scrub, which are dry and highly flammable (Coban and Erdin, 2020). Although there is a strong relation between fire ignition and the temperature, humidity, wind and other environmental circumstances (Duane and Brotons, 2018; Flannigan et al., 2009), Aquilué et al. (2020) claims that the influence of humans on fire regimes is more relevant than weather conditions.

In recent years a change in the pattern of these fires has been observed, more than the number of fires that occur, what is striking is the large areas burnt and the severity of fires (Wunder et al., 2021; Flannigan et al., 2009). Wunder et al. (2021) reviews the series of extremely large and severe wildfires occurred in different Mediterranean areas between 2017 and 2020: Portugal in 2017, Chile in 2017, California in 2018, 2019, and 2020, as well as Australia in 2019 and 2020. The factors behind this change in the forest fire regime include both anthropogenic action and climate change effects (Xifré-Salvadó et al., 2022; Flannigan et al., 2009). Urban areas growth, the abandonment of agricultural crops, and the lack of adequate land-use planning have contributed to an increase in the frequency and intensity of forest fires (Vilar et al., 2016; Moreira et al., 2011). Another determining factor in the change in the fire regime has been climate change (Duane et al., 2019; Cai and Yang, 2016; Aponte et al., 2016). The frequency, intensity and spread of forest fires are being negatively affected by climate change, and this trend is expected to continue in the future

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(Peng et al., 2023). Due to rising temperatures and longer periods of drought, fire intensity is projected to increase in the coming years, leading to more frequent and destructive fires (Sivrikaya and Küçük, 2022; Giannakopoulos et al., 2009). It is therefore important to take action in order to mitigate climate change and reduce the risk of forest fires, as this will have serious impacts on future generations.

Forest fires can result in significant repercussions for biodiversity, the environment and the society. Besides the immediate effects of forest fires, they can also have long-lasting consequences, altering the landscape and the soil composition, increasing soil erosion that would lead to reduce soil fertility (Vieira et al., 2023; Adkins et al., 2019) and disrupting animal habitats that would affect species survival and reduce biodiversity. Forest fires also have economic consequences, causing damage to civil infrastructure and affecting particularly those dependent on forest-based resources and tourism. The impact on society is more evident in the Wildland-Urban Interface areas (WUI), where human settlements are adjacent to wild forest land putting at risk public and private urban infrastructures and even the life of people (Bento-Gonçalves and Vieira, 2020; Michael et al., 2018; Modugno et al., 2016). Moreover, the large amounts of greenhouse gases emitted during a fire event can have an impact on the air quality and climate. It is estimated that wildfire methane emission could represent 5% of the anthropogenic methane emitted to the atmosphere (Xue et al., 2022). Not only do wildfire increase greenhouse gas emissions altering weather patterns, but other reactive gases could produce secondary pollutants that could put at risk human health (Andreae, 2019).

Although measures have been implemented to improve forest fire prevention and management in the region, forest fires remain a recurrent problem. According to Duane et al. (2019) the most common measures adopted to face fire events is related to fire suppression strategies. Despite the economic investment made in recent years in improving the efficiency of firefighting means, both in terms of technology and in the training and education of firefighters (Fernandes et al., 2016), the extinguishing means have become insufficient when facing extreme wildfire events. Moreover, on many occasions, the work of extinguishing fires is conditioned or limited by the topographical characteristics of the affected areas, which are difficult to access. According to Hernandez (2019), in the European Mediterranean region, fire management costs exceed 2 billion euros annually, with 80% of the budget allocated to suppression, while the remaining 20% is used for fire prevention measures. Frequently, the absence of preventive measures and early warning systems is identified as a factor that undermines fire response and control. In the light of this, the efficiency and sustainability of different preventive alternative strategies are being assessed. These include the establishment of monitoring and early warning systems (Casallas et al., 2022), raising public awareness of the importance of forest fire prevention. Other alternative measures are prescribed fires (Vilà-Vilardell et al., 2023; Carrà et al., 2022; Duane et al., 2019), as well as the conversion or recovery of agricultural areas in Mediterranean landscapes (Aquilué et al., 2020). Despite these efforts, the risk of forest fires in the Mediterranean remains high (Shao et al., 2023; Squire et al., 2021), and it is important that measures continue to be taken to prevent and manage them effectively.

A comprehensive approach that encompasses land-use planning, forest management, and the awareness and participation of society is needed. An example of one of this kind of fire preventive measures is the one developed in the GUARDIAN project. The novel and sustainable fire preventive infrastructure developed in this project was settled in a WUI area at the east of Spain in an effort to protect the safety of the citizens and the preservation of the Túria and La Vallesa Natural Park. This pioneering project consists of a preventive irrigation system of sprinkler towers that form a defensive barrier along the forest-urban interface. The hydraulic system is fed with regenerated water from the wastewater treatment plant located in the immediate vicinity of the area to be protected. The implementation of a water regeneration system is an example of a circular economy model in which a residual product (wastewater) is reintroduced in the cycle expanding its useful life and reducing the number of resources extracted from the environment (Castellet-Viciano et al., 2023; Ellen MacArthur Foundation, 2015). Water is a very limited resource in the study area, therefore the use of regenerated water in the hydraulic network of the fire prevention system not only avoids the use of raw water to feed the system but also in the case that a fire event occurs. Nevertheless, wastewater cannot be used directly, and it should accomplish the polices related with the use of regenerated water. In this field, nanotechnology and green nanotechnology could have a great impact to guarantee the sustainability of natural resources and particularly, water (Zinatloo-Ajabshir et al., 2024; Iravani, 2021; Ajith et al., 2021; Zinatloo-Ajabshir and Salavati-Niasari, 2019). The hydraulic system works automatically depending on the weather conditions that a sensor network provides, guaranteeing the humidity of the area that will help to reduce the effects of a fire event. Besides the technological development required to start the automatic irrigation system, GUARDIAN project takes action to enhance the forest's ecological health and fire resistance through the reduction of the density of the trees or clearing the vegetation debris, among other activities. Additionally, the project focuses on community training to boost public preparedness, increase awareness of fire risks, and promote self-protection methods like fire-resistant gardening and safeguarding households.

The natural area protected by this project belongs to a Mediterranean natural park. The Mediterranean area is the second most diverse region in the world (Myers et al., 2000), therefore a regression or worsening of forest quality would increase the pressure on the great diversity of animal and plant species that these forests harbour. Mediterranean forests, like any other ecosystem, have a great natural capital that can hardly be substituted by any human activity. Not only do they offer raw materials such as wood, food, medicines … which are material products useable by humans, but they also offer other services of great value such as soil protection against erosion, carbon sequestration capacity, climate regulation or air quality or support services for the conservation of biodiversity and habitat for different species of animals and plants (Guerra et al., 2016; Palahi et al., 2008). In addition to environmental services, Mediterranean forests have an important social role from a cultural and emotional, recreational, educational, and research point of view.

As pointed by Pacheco and Claro (2023) and Lee et al. (2015) little research focuses on the economic impact quantification of the effects of wildfire on the goods and services provided by natural ecosystems. Therefore, the key innovation of this paper lies in the monetary quantification of the environmental benefits resulting from the implementation of a project aimed at protecting the environment and society. In order to quantify the economic value of the protected area, the Analytic Multicriteria Valuation Method is used, which uses multicriteria decision analysis techniques to assign the value of the different goods or services that the protected natural area can offer through a reference value called "pivot value". The remainder of this paper is organised as follows: in Section 2 the case of study and the methodology is presented, where the study area is described as well as the basis of the Analytic Multicriteria Valuation Method (AMUVAM), method used to quantify the benefits generated by the GUARDIAN project; in Section 3, the results obtained are shown and discussed; finally, Section 4, presents the main conclusions achieved.

2. Methodology

To quantify the externalities of the implementation of Guardian project the Analytic Multicriteria Valuation Method (AMUVAM) is applied. This method has been widely used in recent years to give a monetary value to the environmental benefits (Martín et al., 2017). The AMUVAM method tries to collect all the environmental services present in an area and focuses on those that have a direct value in the market to use them as a reference value ('pivot value') that will permit to estimate the economic benefit of those Environmental Services that have a non-market value. According to (Aznar Bellver and Estruch Guitart, 2020), taking into account the relevance of each one of the ecosystem services it can be established a relationship among them that will permit to estimate the monetary value of all the ecosystem services identified in a specific place. The methodology used in this research primarily involves two distinct stages (Fig. 1).

The first stage focuses on forming an expert panel familiar with the key characteristics and qualities of the study area, with the aim of identifying the main ecosystem services the study area offers (Fig. 2). Generally, ecosystem services are classified into four large groups: i) Supporting services, ii) Provisioning services, iii) Regulating services, and iv) Cultural services. Nevertheless, various classifications can be found in the literature depending on their diversity, functionality, processes, and structure (Camacho Valdéz and Ruiz Luna, 2011; Turner and Daily, 2008; de Groot et al., 2002; Costanza et al., 1997).

The second stage of the AMUVAM method is made up of the Analytical Hierarchy Process, also known by its acronym in English as AHP, and a market "pivot" value. The AHP is a Multicriteria Method, which is based on the Multicriteria Decision Theory, through which several alternatives are compared and chosen taking into account a series of criteria or variables, which are usually in conflict (Saaty, 1980). Therefore, the purpose of this method is to offer a decision-making support tool for complex problems in which different objectives are evaluated and considered in order to make a decision. But the AHP does not give a direct economic value, for this end it is needed to include a pivot value. The purpose of AHP is to identify the relevance of each ecosystem service and establish a relationship among them. However, as a novelty, to quantify the value of the externalities associated with the GUARDIAN project, the AHP method will be replaced by the Analytic Network Process known by its acronym in English as ANP (Analytic Network Process), which is nothing more than a generalization of the AHP.

The ANP is a multi-attribute decision model with which it is intended to solve a discrete decision problem in which, under a series of criteria, an alternative must be chosen among a finite number of them. The choice of the alternative is carried out through the pairwise comparison of the different attributes under different criteria, in which it is asked which are the most important among them through a predefined scale (Fig. 3). However, the ANP is considered a more complete technique, unlike the AHP, it presents a network and non-hierarchical structure, which allows the inclusion of interdependence and feedback relationships between all the elements.

3. Results

3.1. Description of the study area and identification of the ecosystem services offered

The Valencian Community is a region located in the east of Spain, on the Mediterranean coast. Its privileged location along the Mediterranean Sea gives it a great diversity of breathtaking natural landscapes. One of the most outstanding natural parks in this community is the Turia Natural Park, especially important due to its environmental value. Within it is the Vallesa forest, which is a protected natural area. It is a typically Mediterranean forest dominated by pine, olive and carob trees, and the shrub layer is dominated by Mediterranean scrub such as rosemary, thyme, mastic, kermes oak and gorse. As far as the fauna is concerned, there is a great biodiversity of animals, from eagles and owls, to frogs, toads, snakes and martens, mustelids, genets, foxes, wild boars, squirrels and countless other animals.

For example, the Vallesa natural park contains traces of the history of the bordering municipalities of Paterna and Riba-roja del Túria, showing the relationship between nature and human beings. The forest still preserves a network of trenches and bunkers built during the Spanish Civil War, as well as fields of crops, mainly citrus fruits, which take advantage of their proximity to the course of the river Túria and a system of irrigation channels to supply the water resources necessary for their production. It can be said that the environment and the good state of the ecosystems that this natural environment contains generate a flow of environmental goods and services that guarantee the well-being of society. Environmental wealth is the main basis for the social and economic development of a society.

To identify and consequently quantify the externalities linked to the area to be protected in the project a panel of experts made up of different professional profiles involved in the Vallesa environment is created to assess which ecosystem services are significant in the study area. In such a way that the interviewees must be experts in Vallesa and the adjoining

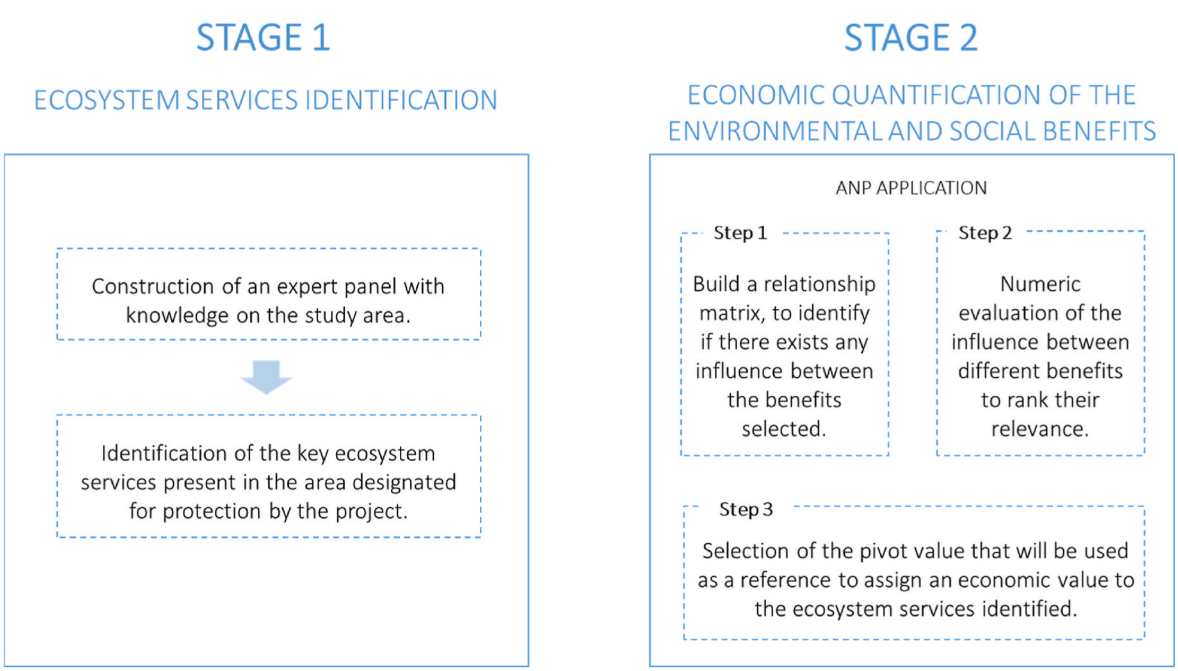

Fig. 1. Methodology implementation diagram.

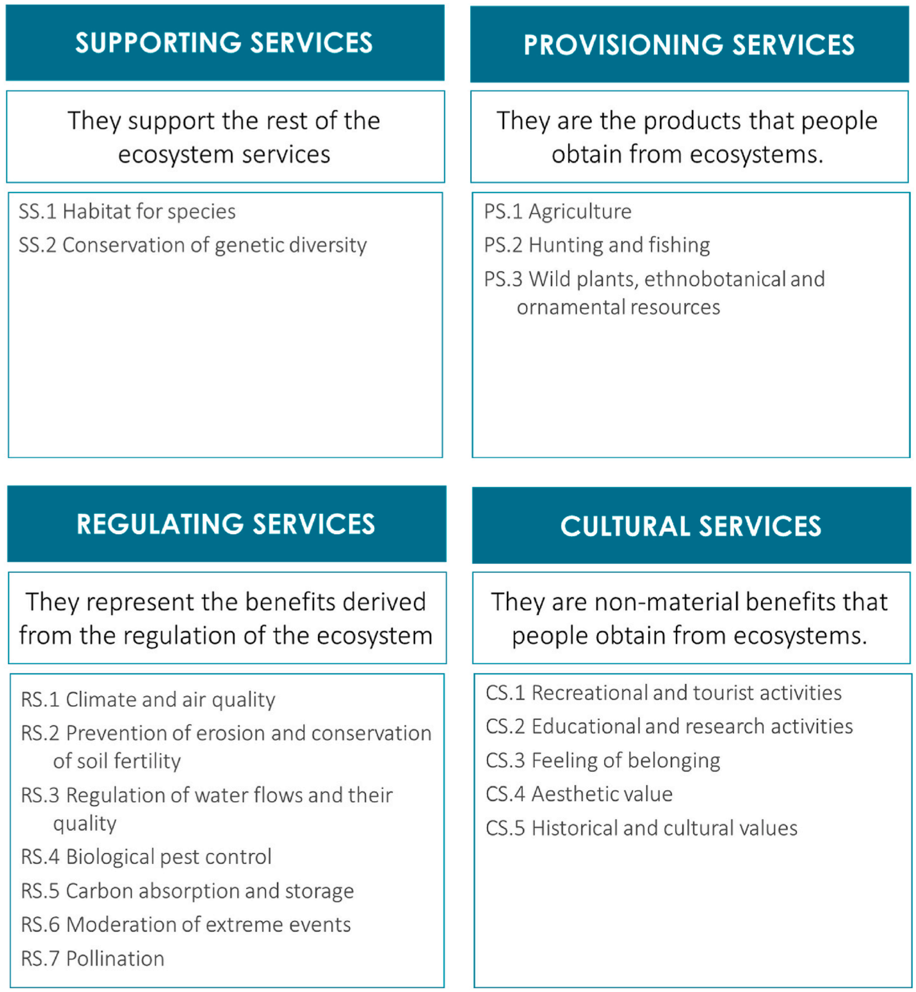

Fig. 2. Ecosystem services. Adapted from Millennium ecosystem assessment, 2005).

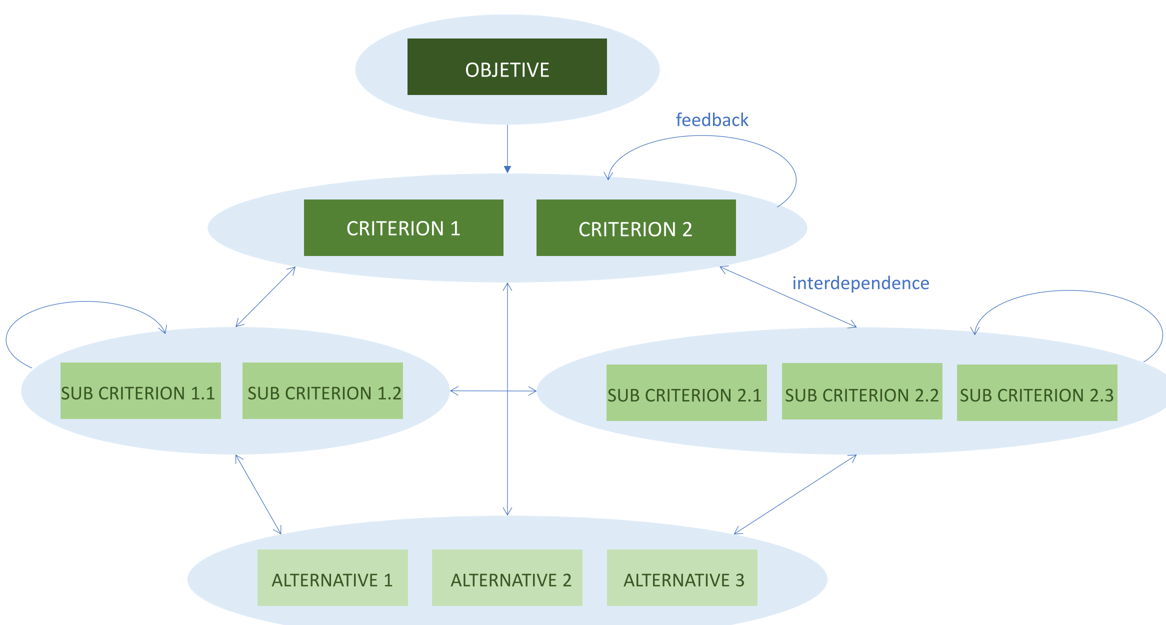

Fig. 3. ANP hierarchical tree structure.

Turia River Park, as well as have an in-depth knowledge of the idiosyncrasy of the municipalities involved in the project, such as Riba-Roja de Túria and Paterna. At this point, it is important to mention that the supporting ecosystem services are not going to be assessed, since they are considered basic services that support the rest of the services, and their relevance is such that it would mask the importance of the rest of the ecosystem services. One of the most relevant aspects is to ensure compliance with properties related to consistency, homogeneity and reciprocity.

3.2. Weighting the ecosystem services

In order to assess the economic value of the ecosystem services identified in the study area, beforehand it is necessary to know the relevance of each one of them. To do this, using the ANP methodology introduced in previous sections, a survey is carried out in which each and every one of the ecosystem services are compared two by two. The survey is carried out with 7 people who are very knowledgeable about the area under study, and experts in different subjects (social and cultural aspects, flora and fauna, environmental issues). This ensures that the findings are not biased and makes the research more robust. The resulting weights obtained for each ecosystem service by each respondent are presented in Table 1.

As it can be observed, the weights can fluctuate depending on the criteria and knowledge of the interviewee. Although the discrepancies among the values given, there are similarities in their responses. For example, many of the interviewees agreed that the least relevant ecosystem service in the study area is *Hunting and fishing* with the exception of the interviewee 1, that considers *Pollination* the least important ecosystem service although *Hunting and fishing* is among the three least relevant ecosystem services. Regarding the most relevant ecosystem services, Interviewees 1 and 4 gave the highest value to *Moderation of external phenomena*; meanwhile interviewees 2, 3 and 5 share the view that *Educational and research activities* is a very significant ecosystem service in the area of study. Finally, interviewees 6 and 7 consider *Recreational and tourist activities* and *Carbon absorption and storage* the most relevant ecosystem services, respectively.

With the aim of analysing how different the responses of the interviewees are, a clustering analysis has been carried out (Table 2). This is a statistical technique that uses distance or similarity measures to group respondents' answers according to a pattern or trend into different groups or clusters. the purpose of this method is to maximise the similarity between elements of the same group while minimising the similarity between groups.

Generally, the cluster analysis identifies 3 weighting trends in most of the ecosystem services analysed, with the exception of: *Hunting and fishing*, *Regulation of water flows and their quality*, *Pollination* and *Feeling of belonging*, in which only two clusters are identified in terms of weighting trends. In this sense, the ecosystem service of *Hunting and fishing*, *Pollination* and *Feeling of belonging* obtain a very low average weighting, around 0.13%, 1.57% and 1.88% respectively, which suggests that the existence of these activities has a much lower impact than the rest of the ecosystem services identified. On the other hand, Regulation of water flows and their quality obtain a higher weighting as well as a more homogeneous weighting trend by the experts, reaching an average of approximately 10 % of the total weighting.

As it has been observed the results offer some differences in the weights obtained by each interviewee, these results are mainly due to the technical profile, experience and knowledge of the area studied. Similarly, the study of the dispersion (standardised values) in the answers given by the experts indicates the existence of certain outliers that can bias the final weightings of the ecosystem services evaluated. In order to avoid any inconsistency in the final values, the M-estimators are calculated. These indicators are a robust alternative to the median or the average values of a sample. An M-estimator is defined as a maximum likelihood estimator, its objective is to find a location index from the set of observations, weighting them according to how close or far they are from the data centre (Cajal et al., 2012). In the case of study, the Huber M-estimator is used to obtain the weight for each one of the indicators. This author uses the constant value K = 1.28 (which corresponds approximately to the z for the central 80% of the data, a central kernel with a 20% trimming). The expression defined to obtain the outliers is the following:

Table 2
Ecosystem service weighting results grouped in clusters.

	CLUSTER 1	CLUSTER 2	CLUSTER 3
Agriculture	0.50%	1.20%	3.00%
Hunting and fishing	0.10%	–	0.30%
Wild plants, ethnobotanical and ornamental resources	0.90%	3.10%	6.90%
Climate and air quality	5.30%	8.40%	11.70%
Erosion and conservation of soil fertility	1.60%	3.30%	5.90%
Regulation of water flows and their quality	9.20%	–	13.30%
Biological pest control	1.80%	3.70%	7.60%
Carbon absorption and storage	3.10%	9.50%	25.80%
Moderation of extreme events	6.50%	13.80%	26.10%
Pollination	0.70%	–	7.10%
Recreational and tourist activities	5.00%	12.90%	20.30%
Educational and research activities	6.90%	13.90%	23.80%
Feeling of belonging	1.30%	–	2.60%
Aesthetic value	1.50%	3.10%	9.30%
Historical and cultural values	4.90%	11.80%	14.00%

Table 1
Ecosystem services weights given by each one of the respondents.

		RESPONDENTS						
		R1	R2	R3	R4	R5	R6	R7
PROVISIONING SERVICES	**Agriculture**	0.76%	0.55%	3.01%	1.06%	0.11%	1.09%	1.55%
	Hunting and fishing	0.34%	0.03%	0.17%	0.10%	0.09%	0.06%	0.11%
	Wild plants, ethnobotanical and ornamental resources	0.14%	2.97%	3.28%	1.28%	1.35%	0.64%	6.93%
REGULATING SERVICES	**Climate and air quality**	7.64%	9.25%	8.30%	12.93%	5.35%	11.07%	11.12%
	Erosion and conservation of soil fertility	3.37%	1.88%	3.53%	3.09%	6.00%	1.24%	5.82%
	Regulation of water flows and their quality	10.58%	8.61%	10.06%	12.56%	14.13%	9.07%	7.55%
	Biological pest control	3.97%	4.01%	7.58%	3.16%	1.02%	1.99%	2.39%
	Carbon absorption and storage	1.31%	11.72%	8.89%	4.19%	7.99%	3.82%	25.81%
	Moderation of extreme events	29.01%	4.44%	7.93%	23.14%	6.98%	14.70%	12.95%
	Pollination	0.03%	1.62%	1.80%	0.23%	0.14%	0.11%	7.09%
CULTURAL SERVICES	**Recreational and tourist activities**	19.70%	3.86%	5.26%	15.20%	10.61%	20.89%	5.93%
	Educational and research activities	7.99%	25.34%	20.68%	7.12%	25.46%	13.94%	5.44%
	Feeling of belonging	1.61%	1.54%	2.67%	2.27%	2.90%	1.63%	0.52%
	Aesthetic value	0.91%	10.51%	3.49%	8.65%	2.79%	8.73%	2.09%
	Historical and cultural values	12.62%	13.65%	13.35%	5.02%	15.09%	11.02%	4.71%

$|X-M|/_{MAD}/0,6745 < 1,28$

Finally, Fig. 4 represents the weight of each one of the ecosystem services obtained from the interviewee's answers. As it can be observed, the least relevant ecosystem services with a weight equal or lower than 2% are: *Hunting and fishing* (0.10%), *Pollination* (0.30%), *Agriculture* (1.00%), *Wild plants, ethnobotanical and ornamental resources* (1.90%), *Feeling of belonging* (2.00%). After them, the ecosystem services with a weight value between 2% and 6% are: *Biological pest control* (3.20%), *Erosion and conservation of soil fertility* (3.60%) and *Aesthetic value* (5.40%). In the range between 6% and 10% we only find the *Carbon absorption and storage* (7.80%). The relevance of the next block of ecosystem services ranges between 10% and 14% and they are: Climate and air quality (10.10%), Regulation of water flows and their quality (10.70%), Recreational and tourist activities (11.80%), Historical and cultural values (13.00%), Moderation of extreme events (13.50%). Finally, the most relevant ecosystem service is Educational and research activities with a weight of 15.70%.

3.3. Obtaining the pivot value

Next, the pivot value, which is obtained from those ecosystem services that have a market value is calculated. The resulting number is used as a reference to assign an economic value to the rest of the ecosystem services that do not have a market value. In the research carried out by Azanar et al. (2011) used the rize price to obtain the economic value of the Ebro natural Park in Catalonia, Spain. Equally, Estruch-Guitart and Vallés-Planells (2017), use the price rise for the economic valuation of the landscape aesthetics in Albufera Natural Park, in Valencia (Spain). Similarly, other authors such as Barrial-Lujan et al. (2022), to assess the economic value of The Pacucha Lagoon Ecosystem use the price of other agricultural products such as potato, corn, alfalfa and vegetables, together with livestock and fishing. In the current project area, activities such as agriculture, hunting, and fishing have little economic impact, while recreational, educational, and research activities are not carried out for economic purposes. On the contrary, in the current research *Carbon absorption and storage* is identified as one of the most relevant ecosystem services that could have a market value. As it has been observed in the literature, little research has used as pivot value the CO_2 eq sequestration (Araca et al., 2021). The Directive 2003/87/EC of the European Parliament and of the Council established the EU Emissions Trading Scheme (EU ETS), which is a market instrument that pursues an environmental purpose to implement the polluter pays principle, created the concept of an allowance, which establishes the economic value of CO_2 emissions through emission rights. Making use of this value the environmental benefit, in economic terms, that the Vallesa area is generating by reducing the CO_2 present in the atmosphere through the CO_2 fixation capacity of the forest is calculated. To this end it is necessary to assess the CO_2 absorption capacity of the area. Following the studies of Montero et al. (2020), Luque et al. (2017), Ruiz-Peinado et al. (2011) and, Piñol and Vilalta (2006) which present calculation methodologies developed for the estimation of CO_2 absorption, providing detailed information on the CO_2 absorption of different tree forest species, it has been obtained that the equivalent CO_2 emissions burnt in case of fire in the area protected by the Guardian project would reach a value of 45.99 t/ha of CO_2 equivalent (Fischer and Heine, 2023).

Generally, in the economic evaluation of public projects and particularly in the case of environmental assets, as in the Guardian project, it is assumed that these assets will remain unchanged over a long period of time, so a time horizon of 100 years is used for the evaluation (Tietenberg and Lewis, 2018), therefore the social discount rate (SDR) is used, which includes the criterion of equity in addition to the opportunity cost of the resources invested in the project. The inclusion of the SDR in decision-making has become more relevant due to the need for administrative transparency and evidence of the social and environmental externalities of projects. As there are different methodologies for calculating the SDR, there is no single value for the SDR, which can lead to very different effects on decision-making. For example, taking a high SDR as a reference may lead to the rejection of socially desirable projects, while a too-low SDR may result in wasting resources on economically inefficient projects (Zhuang et al., 2007). In this project, an SDR of 3% will be used, which is the value used in Spain for water-related projects (Castillo and Zhangallimbay, 2021). Therefore, using the

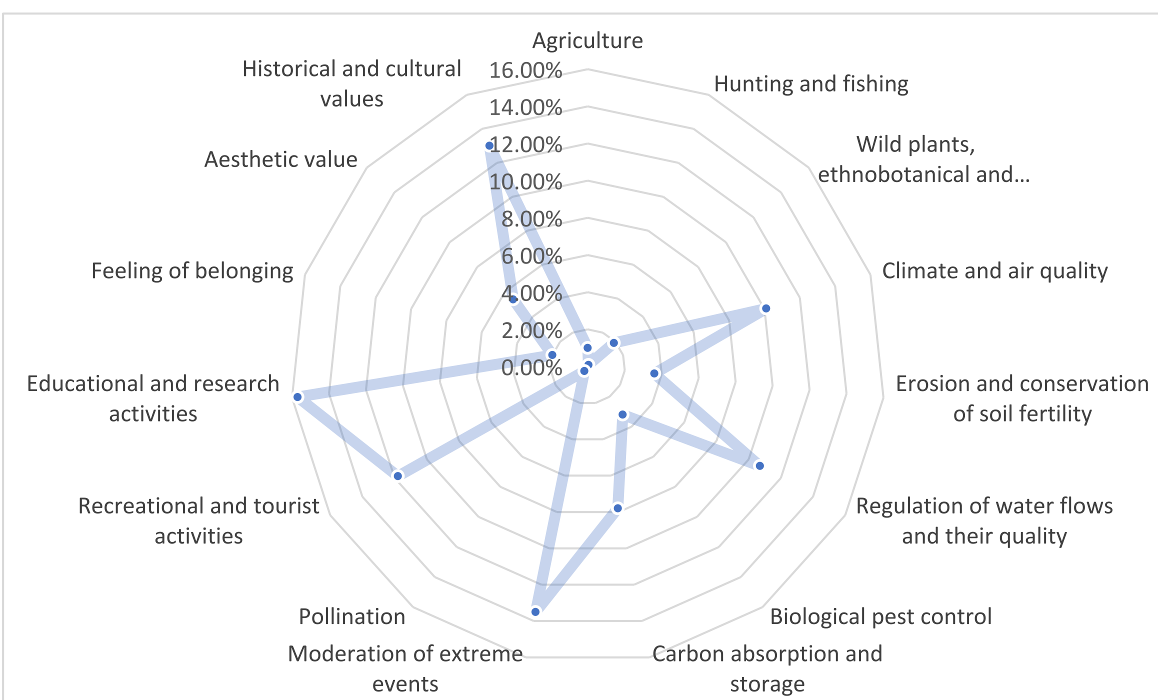

Fig. 4. Aggregated weighting result through Huber M-estimators.

equation for updating rents for environmental assets, we can conclude that the ecosystem service related to the absorption and storage of carbon in the Vallesa is valued at 32,836,860 €.

3.4. Economic valuation of ecosystem services in the study area

Taking into account the relevance of each of the ecosystem services in the project environment and using the economic value of the ecosystem service *Carbon absorption and storage* as a reference, we can quantify the value of the rest of the ecosystem services offered by the Vallesa. As it has been presented in previous sections, the interviewees' responses have not been unanimous or homogeneous for all ecosystem services, and some trends have even been observed when valuing them (cluster analysis). Therefore, when assigning an economic value to the area affected by the GUARDIAN project, we consider it more appropriate to give a value with a margin of tolerance or uncertainty.

To generate the margin of tolerance or uncertainty of the economic value of the project's study area, we will base ourselves on the cluster study carried out (Table 2), focusing on the values obtained for the ecosystem service *Carbon absorption and storage*. As it can be seen, three trends can be distinguished when weighting this ecosystem service: cluster 1, the weightings are clustered around 3.1%; cluster 2, there is a certain tendency to weight this ecosystem service at around 9.5%; and finally cluster 3 shows an inclination in the weightings towards 25.8%. As pointed out by De Menezes et al., (2021), in non-symmetrical distributions it is convenient to use the M-estimator, from its calculation maximum and minimum tolerances are established that respond to the global deviation of the responses between clusters. In this way, a tolerance range of ±17.89% is established with respect to the average value using the M-estimators. Table 3 below shows the economic value of each ecosystem service and the total amount for the Vallesa area:

Finally, we can conclude that the natural environment of La Vallesa is valued between 338,035,481 € and 485,384,281 €. Similarly to this research, there exist many studies that try to quantify the economic value of tangible and intangible natural resources in different countries, however, the methods applied for its calculation differ a lot from one to the other and results should not be compared. Nevertheless, several studies that use the AMUVAM methodologies have been found (Table 4). As it can be observed, most of the studies in which the AMUVAM method has been used aim the quantification of aquatic landscapes, for this reason the economic value obtained in this research cannot be directly compared with the environmental value of La Vallesa. However, the work of Araca et al. which purpose is to quantify the value of a high-Andean forest in Peru has obtained an economic value that ranges between 32,641,387 - 102,098,052 USD, this value is closer to the one obtained for la Vallesa. Despite the use of the same methodology and its application in the same context, it is expected that some differences in the results may arise, as this methodology is based on expert opinion and is therefore subjective, reflecting the varying sensitivities of these experts towards specific ecosystem services.

Table 3
Economic value of the ecosystem services of the Vallesa and surrounding area.

Ecosystem services	Minimum Value (€)	Mean Value (€)	Maximum Value (€)
Agriculture	3,380,355	4,117,099	4,853,843
Hunting and fishing	338,035	411,710	485,384
Wild plants, ethnobotanical and ornamental resources	6,422,674	7,822,488	9,222,301
Climate and air quality	34,141,584	41,582,698	49,023,812
Erosion and conservation of soil fertility	11,831,242	14,409,846	16,988,450
Regulation of water flows and their quality	36,169,796	44,052,957	51,936,118
Biological pest control	10,817,135	13,174,716	15,532,297
Carbon absorption and storage	26,366,768	32,113,371	37,859,974
Moderation of extreme events	45,634,790	55,580,834	65,526,878
Pollination	1,014,106	1,235,130	1,456,153
Recreational and tourist activities	39,888,187	48,581,766	57,275,345
Educational and research activities	53,071,571	64,638,451	76,205,332
Feeling of belonging	6,760,710	8,234,198	9,707,686
Aesthetic value	18,253,916	22,232,334	26,210,751
Historical and cultural values	43,944,613	53,522,285	63,099,957
TOTAL	**338,035,482**	**411,709,883**	**485,384,281**

Table 4
Environmental quantification using the AMUVAM method reported in the literature.

Reference	Ecosystem Valued	Quantification Method	Economic Value
Azanar et al. (2011)	Park of Ebro River Delta in Catalonia (Spain)	AMUVAM	32,402 €/ha
Estruch-Guitart and Vallés-Planells (2017)	Albufera natural park in Valencia (Spain)	AMUVAM	4314 USD/ha year
Barrial-Lujan et al. (2022)	The Pacucha lagoon located in the Apurimac region (Peru)	AMUVAM	176.20 USD/m^3
Romero et al. (2020)	Santa Elena Lake (Chile)	AMUVAM	17,780,686 USD
Araca et al. (2021)	High-Andean forest (Peru)	AMUVAM	32,641,387 - 102,098,052 USD

If we analyse the individual value of each ecosystem service, it can be observed that the one with the lowest value in the natural park of La Vallesa is related to *Hunting and Fishing* with an economic value that ranges between 338,035 € and 485,384 €, and on the other hand, the most valued is related to *Educational and research activities*, whose value ranges between 53,071,571 € and 76,205,332 €.

The previous results show that the economic value of the study area is mainly determined by Regulatory and Cultural ecosystem services, which represent the 93% of the total value, with very similar contributions: 49% corresponding to Regulatory services (165,975,421 - 238,323,682 €), and 48% to Cultural services (161,918,996 - 232,499,071 €). The remaining 3% of the economic value of the study area is contributed by Provisioning ecosystem services (10,141,064 - 14,561,528 €), making it the least relevant group (Fig. 5).

Analysing in detail the economic value of each of the Provisioning ecosystem services within this group of ecosystem services as a whole (Fig. 6), it can be observed that *Wild plants, ethnobotanical and ornamental resources* account for 64% of the value, followed by *Agriculture* with 33% and *Hunting and fishing* with 3%.

As far as Regulating ecosystem services are concerned (Fig. 7), 85% of the value of this group of ecosystem services is provided by: the *Moderation of extreme events*, the *Regulation of water flows and their quality*, C*climate and air quality* and *Carbon absorption and storage*, with 27%, 22%, 21%, 16%. While *Erosion and conservation of soil fertility* (7%), *Biological pest control* (6%) together with *Pollination* (1%) account for the remaining 15% of the value of Regulating ecosystem services.

Finally, Fig. 8 shows the economic value of Cultural ecosystem services, which is mainly represented by *Educational and research activities*, *Historical and cultural values*, and *Recreational and tourist activities*, which contribute 33%, 27% and 25%, respectively. The ecosystem services with the lowest value are *Aesthetic value* and *Feeling of belonging*, which contribute with the 11% and 4% of the economic value of cultural services, respectively.

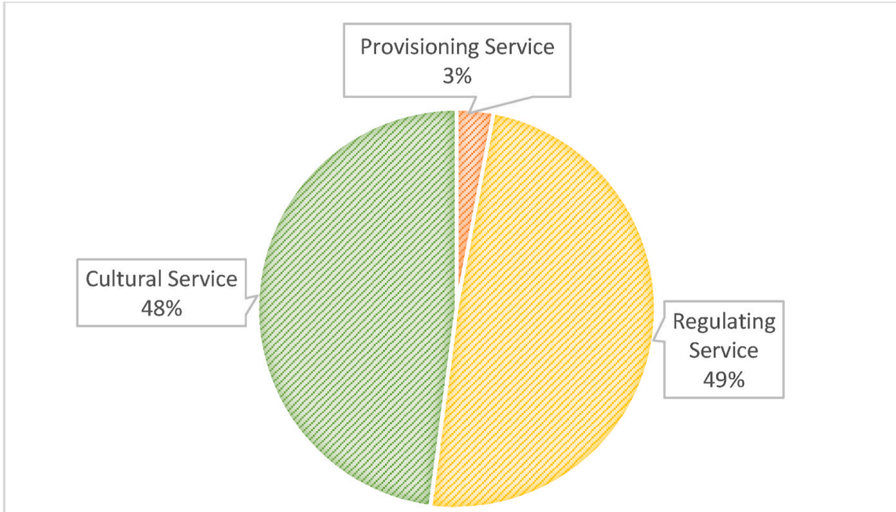

Fig. 5. Economic value of ecosystem services per group expressed in %.

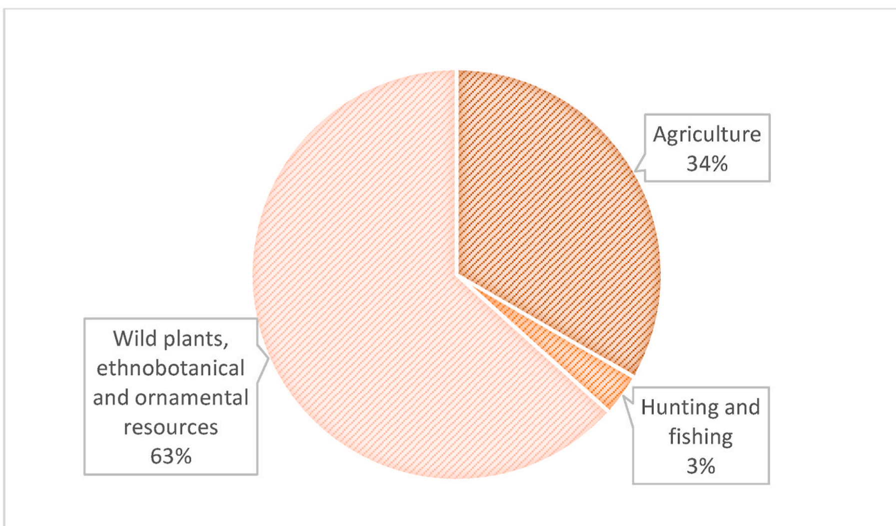

Fig. 6. Economic value of provisioning ecosystem services (%).

4. Conclusions

Forest fires are a growing problem in our country, being more frequent and virulent due to the conditions caused by climate change. The combination of hot and dry climate, dry and flammable vegetation, rugged terrain and human use of the territory make the Mediterranean region particularly prone to forest fires. Not only could fires cause direct damage to the lives of people and their property, but they have also very negative consequences on the ecosystems and the goods and services they provide. For this reason, it is important to take preventive fire management measures to reduce the frequency and intensity of fires such as the strategy developed in the GUARDIAN project. In order to demonstrate the benefits generated by this type of project, the present study has been conducted, whose main contributions are outlined below.

- the environmental and social services offered by the natural area protected by th GUARDIAN project have been economically quantified using the AMUVAM methodology. As a novel contribution, this monetary quantification addresses one of the main challenges faced by projects aimed at generating environmental and social benefits—evaluating these benefits in economic terms.
- Based on the information and calculations presented in this study, it is estimated that the GUARDIAN project currently safeguards a natural environment valued at approximately €338,035,481 to €485,384,281.
- These results highlight the need and value of protecting natural environments, and specifically the natural area of La Vallesa through the implementation of the GUARDIAN project.
- More particularly, the results reveal that within different categories, regulating and cultural ecosystem services carry nearly equal significance:
  - o Among the regulating services, certain aspects stand out:
    - *moderation of extreme events*, vital in an area prone to heavy rainfall and droughts like the Valencian Community;
    - the *regulation of water flows and their quality*, essential due to water scarcity and flood risk, as well as ensuring irrigation for nearby crops through La Vallesa's artificial wetland, and the ability to absorb water, crucial for flood control;

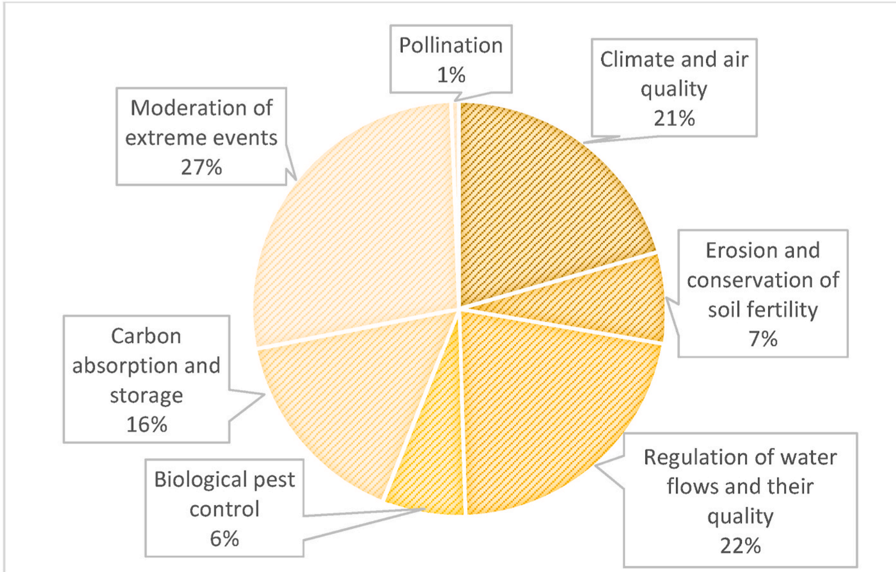

Fig. 7. Economic value of regulation ecosystem services from (%).

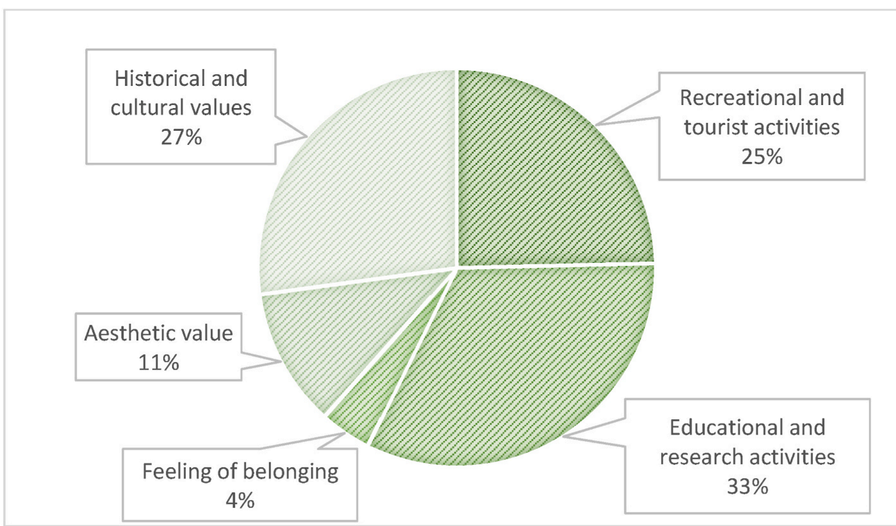

Fig. 8. Economic value of cultural ecosystem services (%).

- lastly, the *carbon absorption capacity* plays a key role in maintaining good air quality in the Valencian region and the metropolitan area of Valencia.

o As far as cultural services are concerned, the most highly valued were those related to:

- *educational and research activities*, as there are numerous educational activities for schoolchildren and numerous research activities related to the flora and fauna of the area, for example;
- *recreational and tourist activities*, with many visitors from the local area and other municipalities coming to enjoy the environment and carry out recreational activities;
- and finally, *cultural values*, mainly due to the historical ties that link the natural park with the neighbouring population, being the scene of the events of the civil war that are still preserved through the network of trenches and bunkers.

It should be borne in mind that any type of methodology based on knowledge or social perception is not exempt from subjectivity, so when interpreting or using the results offered by this type of methodology it is necessary to take this into consideration. However, methodologies such as the one developed in this research allow for an estimation of the economic value of environmental and social benefits that do not have a market price. Demonstrating the economic feasibility of this kind of project is not enough to guarantee their implementation, a crucial factor in addressing fires and climate change is society's adaptability. This adaptability hinges not only on scientific and technical expertise but also on the collaboration and engagement of all stakeholders, including citizens, financial support from public and private entities, and the implementation of regulations and legislation at the political level. This collective effort is what enables initiatives like the GUARDIAN project to be effectively carried out.

CRediT authorship contribution statement

Lledó Castellet-Viciano: Writing – original draft, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Vicent Hernández-Chover:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization. **Francesc Hernández-**

Sancho: Writing – review & editing, Supervision, Investigation, Conceptualization.

Declaration of competing interest

The authors are not aware of any financial interests or personal relationships that might have influenced the objectivity or findings of this study.

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Data availability

The data that has been used is confidential.

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