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Wildfires' Cost for Societal Welfare: Economic Evaluation of Forestry Ecosystem Services Losses in Southern Italy

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ABSTRACT

Forest ecosystem services (ESs) are garnering increasing public attention as awareness grows regarding society's fundamental dependence on them for well-being. Forest fires, one of the major disturbances of ESs, are becoming more frequent and destructive, exacerbated in part by climate change. Quantifying the value of ESs can foster responsible behavior and offer suggestions to public decision-makers in planning activities and mitigating damaging events. The objective of this study is to provide a monetary valuation of the reduction in ESs' use value in a protected forest area in southern Italy. The study focused on the Aspromonte National Park (ANP) in Calabria, a region with typical Mediterranean characteristics, which experienced a significant fire in August 2021. By combining a geographic information system (GIS) and field surveys with tailored estimation methodologies rooted in the total economic value (TEV) approach, the study effectively addressed the distinctive variables of both ESs and the forest, enabling the economic quantification of the resulting loss. The analysis showed that the total damage amounted to roughly €26 million. The ESs with the highest incidence of economic damage were identified as hydrogeological protection, wood resources, and naturalistic function. Following this, a detailed valuation of the most representative forest categories was conducted, revealing that all systems, including the simplest ones, possess substantial value and fulfill specific ecological roles. Findings establish a promising framework for informing silvicultural strategies and represent a suggestion system to identify damage phenomena and safeguard the continued existence of forests and the ESs they provide.

1 | Introduction

1.1 | Ecosystem Services (ESs) and Total Economic Value (TEV)

Global research in the third millennium increasingly emphasizes the sustainable management of natural resources, biodiversity conservation, and adaptation to climate variability (Esham et al. 2018; Laface et al. 2024; FAO 2024).

Furthermore, there is a growing recognition of the fundamental dependence of human livelihoods and well-being on the diverse goods and services supplied by the environment (Pettenella et al. 2008; Liu and Wu 2021).

The provision of benefits by natural and seminatural ecosystems, known as ESs, has been the focus of research for several years. Specific classifications have been proposed (Costanza et al. 1997; Costanza 2024; De Groot et al. 2002; Millennium Ecosystem Assessment 2005; Farber et al. 2006; Soldati et al. 2023) to allow comparisons and trade-offs between the relevant set of potential benefits (Wallace 2007). However, when the ultimate goal involves application in decision-making contexts that require economic valuation, a more targeted classification methodology becomes necessary (Fisher et al. 2009). In this regard, a significant example of this evolution is represented by the Economics of Ecosystems and Biodiversity–TEEB (2010) framework. Although TEEB explicitly references the cascade model and refines the Millennium Ecosystem Assessment classification, it introduces important distinctions: notably, it perfects the separation between services and benefits and introduces the new group of "habitat services," which includes "maintenance of life cycles" and "maintenance of genetic diversity" (La Notte et al. 2017).

The importance of ecosystems and their associated services has been interpreted in different ways by various disciplines, cultural perspectives, philosophical traditions, and schools of thought (Goulder and Kennedy 1997). At the basis of the provision of ESs is natural capital, defined as "those elements of the natural environment that provide goods and services of value to people" (NCC 2017, 2). Assessing the value of natural capital is crucial for determining the optimal allocation of resources to restore, maintain, and manage the natural environment.

Consequently, an economic framework, as outlined in the following study, offers a means to quantify ESs, thereby contributing to a more comprehensive understanding of the interconnectedness between ecosystems and human well-being (Pandeya et al. 2016; A. I. De Luca, Iofrida, et al. 2023; G. De Luca, Modica, et al. 2023).

Globally, forests are paramount in providing ESs (Felipe-Lucia et al. 2018; Miura et al. 2015) and support the highest levels of biodiversity.

Consequently, various methods for assigning monetary values to the forest ESs have been explored over time. This need has become increasingly evident, particularly with the rise of "environmental consciousness" in the 1970s (De Groot 1987; Gómez-Baggethun et al. 2010), and to underscore the often underestimated economic importance of natural resources (Hardin 1968; Ingaramo et al. 2017).

In the 1990s, the TEV concept arose (Peterson 1987; D. Pearce 1993; Merlo and Croitoru 2005; Marone and Sacchelli 2014), as an attempt to answer this increasing need. TEV enables a comprehensive and systematic valuation of environmental assets by, among other things, monetizing the benefits derived from ecosystems (Bottaro et al. 2022; Ingaramo et al. 2017; Thorsen et al. 2014).

The TEV framework recognizes the varied nature of environmental goods by disaggregating them into two components: "use value" derived from direct physical interaction based on utilitarian principles, and "nonuse" values that exist independently of such interaction (D. W. Pearce 1992; Groombridge 1992).

In the ES framework, the term "use value" is employed to denote the value of ESs utilized by humans for purposes of consumption or production. This encompasses both tangible and intangible ESs that are currently being used directly or indirectly, as well as those that possess the potential to provide future use values. The direct use value implies a voluntary direct fruition of the environmental asset. Benefits are divided into extractive (derived from harvesting raw materials, flora, fauna, etc.) and non-extractive (derived from the enjoyment of an environmental service, such as tourism and recreational activities). The indirect use value refers to the benefits derived from the involuntary fruition of the asset, which are the services the ecosystem provides indirectly (e.g., hydrological protection, carbon sequestration, and improved air quality). The potential use value is connected to the possibility of utilizing the resource in the near future under risk conditions. It expresses the willingness to pay to conserve environmental systems that the individual is likely to use in the future. This value also encompasses the distinction of the quasi-option value (Arrow and Fisher 1974), which specifically represents the willingness to preserve the option to use the asset, recognizing that the decision to maintain the asset today avoids the risk of future regret associated with irreversible loss.

In the context of this study, the methodological choice was to consider both direct and indirect use values, the estimation of which was intrinsically determined by the availability of specific primary data surveyed in the area affected by the damage. This approach, in strict adherence to the principles of appraisal/valuation discipline, ensures the achievement of an empirical, objective result characterized by methodological rigor.

The nonuse value of ecosystems refers to the value assigned based on social-ethical principles, independently of direct or indirect use. Driven by non-utilitarian motivations and preferences, this value reflects the satisfaction individuals derive from the mere existence of a resource, even in the absence of personal use, and from the knowledge that ESs are maintained and available for the benefit of others across time (Kolstad 2000).

Although fire is widely recognized as a key ecological driver globally (Bowman et al. 2009; Xu et al. 2021) and can produce beneficial effects, such as reducing stand density and competition in mono-specific forests (Trentini et al. 2020), calculating this function as an ES is highly complex and risky, especially in the Mediterranean context. The resulting environmental impacts are severe: wildfires, for instance, can trigger or sustain the invasion of alien species (Wells et al. 2021; Saulino et al. 2023) and, when frequent, they may initiate severe soil degradation processes. This leads to a loss of ecosystem resilience through reduced vegetation cover, alteration of microbial communities (Guénon et al. 2011), depletion of soil organic matter (Bowd et al. 2019), and increased erosion, which ultimately risks desertification in Mediterranean environments (Rutigliano et al. 2007; Ramón Vallejo et al. 2012). Given that the high risk of irreversible degradation and potential for invasive species outweigh the potential, uncontrolled, and short-term biodiversity gains, forest management strategies offer a safer and more predictable pathway. For instance, interventions like thinning achieve similar biodiversity goals by promoting native understory development through increased solar radiation (Dang et al. 2018), without the inherent hazards of uncontrolled wildfire.

1.2 | Forest Fires in Europe

Forest fires represent the most significant disturbances with the potential to compromise the ecological integrity of forests

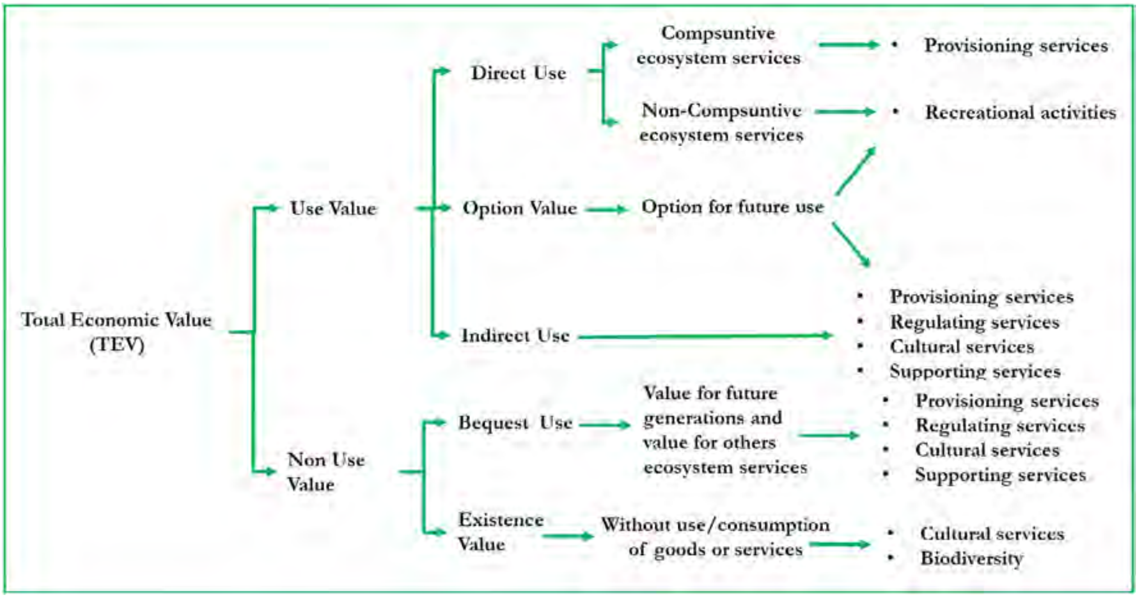

FIGURE 1 | Components of the total economic value (TEV) in forest ecosystems. *Source:* Authors' elaboration from Turner et al. (1994) and Merlo et al. (2000). [Colour figure can be viewed at wileyonlinelibrary.com]

(USDA 2000; Thom and Seidl 2016; Spatola et al. 2023). This phenomenon is particularly prevalent in regions like the Mediterranean area due to specific climatic conditions (Schelhaas et al. 2003; Bovio et al. 2014) and causes substantial ecological and economic damage annually, also generating negative externalities, such as air emissions from burning wood (Carbone 2005).

Furthermore, fire recurrence has increased in recent decades and is expected to continue rising under future climate scenarios (Kovats et al. 2014; El Garroussi et al. 2024).

While forests can regenerate naturally, post-wildfire recovery (in the absence of human intervention) is determined by factors such as fire regime, burned forest composition, and biophysical conditions (Lopes et al. 2024). Additionally, drought and high temperatures can prevent successful tree regeneration.

Economic valuation of environmental assets can improve protection decisions (D. W. Pearce 1992) by providing understandable values. Quantifying fire damage losses, from an ES's point of view, can raise public awareness beyond media portrayals and help decision-makers create prevention and mitigation strategies (Pausas and Keeley 2021; Silvestro et al. 2021).

Europe is heavily affected by forest fires. Annually, around 400,000 ha are destroyed (Eurostat 2024), with the Mediterranean region (Portugal, Spain, Italy, Greece, and France) accounting for about 85% of the total European area burned (Gomes et al. 2020).

The abandonment of rural areas in these countries in recent decades is a significant cause for concern (Lasanta et al. 2017). This has led to the encroachment of vegetation, landscape homogenization, and an increase in fuel loads. These conditions, coupled with a lack of effective forest management and more frequent heat waves, have contributed to the development of highly flammable environments (Gomes et al. 2020; Pausas and Keeley 2021).

Italy ranks among the European countries with the most frequent and extensive fires annually (Copernicus 2023). Southern Italy, including Calabria, is heavily impacted. From 2010 to 2023, Calabria saw 2147 fires affecting 147,800 ha (average ~ 18,397 ha/year in 2020–2023, 70% forest) (Copernicus 2023). Consequently, this study's objective is to monetarily quantify the lost use-value ESS from the summer 2021 forest fire in a protected area in the Calabria region. The analysis addresses the following research questions:

RQ1. What is the economic impact of fire-induced losses or damage to the individual ESs?

RQ2. How does the economic value of these losses vary with the intrinsic characteristics of forest ESs?

The research centered on the municipality of Roccaforte del Greco, a mountainous village in the Aspromonte National Park (ANP), and used primary data directly collected in the fire-affected areas, established market-based valuation techniques, and GIS techniques. To the authors' knowledge, this represents the first monetary valuation of fire damage and ES loss in a southern European protected forest integrating GIS into the estimation methodology.

2 | Materials and Methods

2.1 | Study Area

This case study focuses on part of the ANP, a 64,544.61-ha protected area, established in 1989 in Calabria (Southern Italy), one of Europe's southernmost regions (Figure 1). In the summer of 2021, the ANP was hit by severe forest fires (ISPRA 2024; Bombino et al. 2023, 2024; G. De Luca, Modica, et al. 2023), impacting 15,000 ha, of which roughly 5000 were wooded (Figure 2).

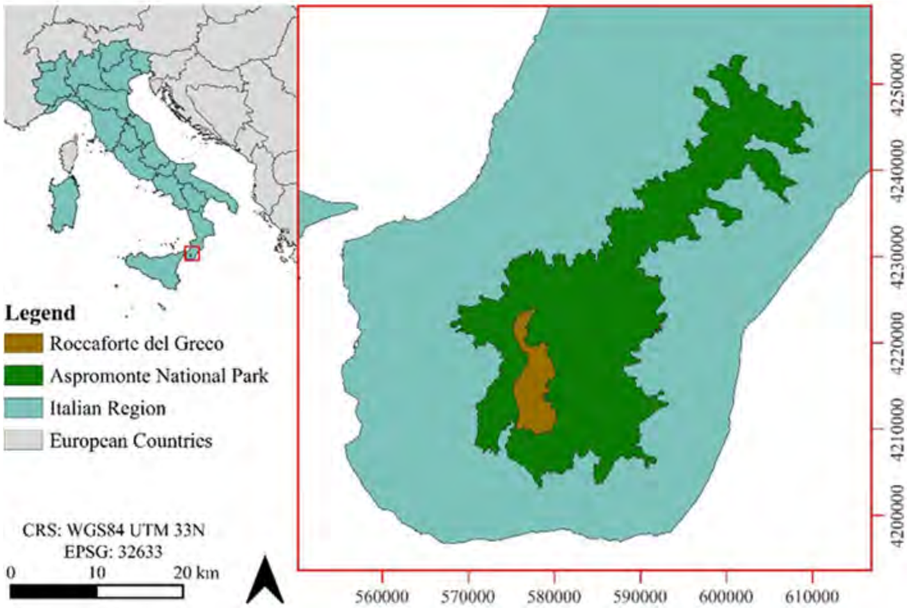

FIGURE 2 | Geographical location of the case study in the ANP. *Source:* Authors' QGIS software processing. [Colour figure can be viewed at wileyonlinelibrary.com]

Fueled by canopy spread, the fire's intense nature caused significant damage across the forest area and to highly valuable natural and landscape sites. Notably affected were ancient beech forests ("Valle infernale," a UNESCO World Heritage Site) and over 500-year-old pine forests (the so-called "Acatti" and "Afreni" forests) (Bombino et al. 2023).

The fire area's significant ecological importance stems from its diverse bioclimatic zones, each supporting a unique array of plant species (Spampinato et al. 2007; Musarella et al. 2024).

The following list provides a detailed account of the territorial division and the tree species that have been observed in the area.

- *Lower Supra-temperate* (1200–1400 m a.s.l.): Fagetalia sylvaticae forests (Galio irsuti-Fagetum *Abies alba* var. apenninao with *Pinus nigra* ssp. calabrica); Natural pine forests (below 1400 m): *Pinus nigra* ssp. calabrica with Quercus congesta and Quercus dalechampi.
- *Supra-Mediterranean* (900–1200 m a.s.l.): Quercus congesta woods with shrub layer (*Erica arborea*, *Cytisus villosus*) and herbaceous layer (*Festuca heterophylla*, Poa sylvicola); Artificial chestnut woods.
- *Humid/Hyper-humid Meso-Mediterranean*: *Quercus ilex* with Teucrio siculi.
- *Thermo-Mediterranean*: Euphorbia arborea associated with Olea europea ssp. Sylvestris and *Pistacia lentiscus*.

Natural vegetation differs from artificial formations resulting from reforestation efforts funded by Calabria's Special Law (nos. 1177/1955 and 47/1968). These laws supported soil protection, degraded land recovery, and, from the late 1970s, wood production (Siniscalco et al. 2018).

Based on the naturalistic and ecological value of its forest, the ANP is divided into zones with different protection levels. This zoning adheres to Framework Law (no. 394/1991, art. 12, para. 2) to ensure forest conservation and sustainable management. The homogeneous zones are as follows:

- *Zone A* (Integral Reserve—10,024.41 ha): Natural environment preserved in its original state.
- *Zone B* (General-Oriented Reserve—28,061.88 ha): New construction and territorial transformations prohibited, but traditional uses, essential infrastructure, and park authority resource management allowed.
- *Zone C* (Protection Areas—18,498.51 ha): Traditional farming, fishing, and collecting permitted under park authority criteria. Maintenance, restoration, and conservation of existing architecture allowed.
- *Zone D* (Economic and Social Promotion Areas—3744.36 ha): More anthropised areas where activities compatible with park purposes and aimed at improving local socio-cultural life and visitor enjoyment are permitted.
- *Zones Cs and Ds* (Special Areas—1650.59 and 498.85 ha): Smaller areas within Zones C and D with specific characteristics requiring management.
- *Non-zoned areas* (2066.02 ha): Areas resulting from the 2008 perimeter adjustment, subject to general protected area principles (AIB 2019).

2.2 | Collecting Data

This study focuses on the 2491.83 ha affected by fire within the Roccaforte del Greco municipality, of which 44% were classified as forest. Burnt area data, sourced from the near-real-time EFFIS (European Forest Fire Information System 2024) MODIS (Moderate Resolution Imaging Spectroradiometer) satellite database (a polygon shapefile containing fire details), were queried using QGIS to isolate areas within Roccaforte del Greco during

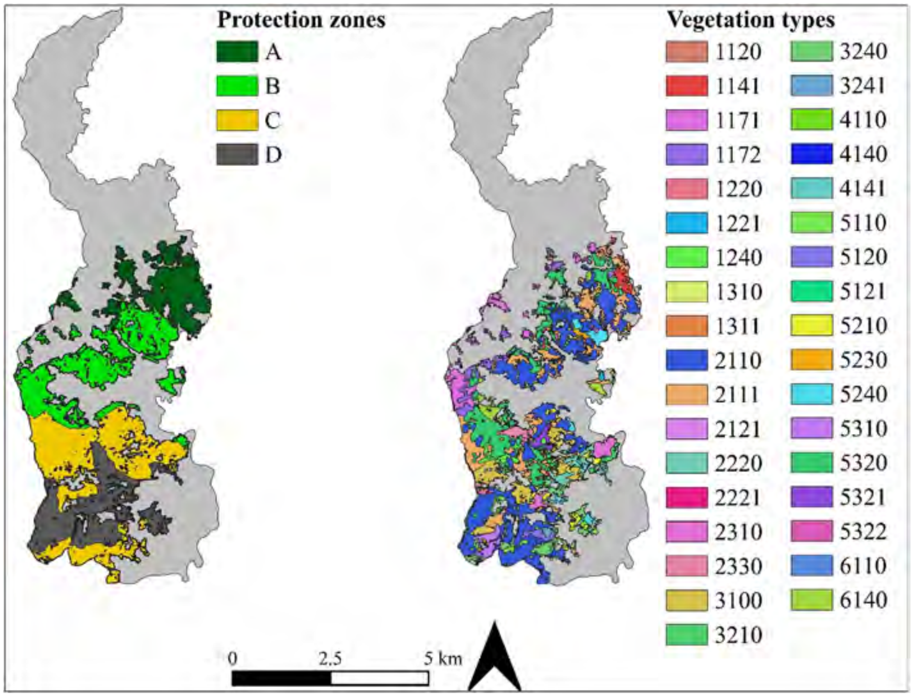

FIGURE 3 | Land use in the fire-affected area and ANP's protected areas. *Source:* Authors' QGIS software processing. [Colour figure can be viewed at wileyonlinelibrary.com]

the August 2021 wildfire. EFFIS is a web-based, modular geographic information system part of the Copernicus program, under the emergency management service, able to provide near-real-time and historical data of forest fires in the European Union (EU) countries and other non-EU Mediterranean countries, licensed under the Creative Commons Attribution 4.0 International (CC BY 4.0). Subsequently, according to Bombino et al. (2024), the acquired polygons were overlaid in a GIS environment with shapefiles of ANP protection zones and vegetation types (open-access data available on the ANP website; Figure 3) to analyze the specific zones and vegetation impacted by the fire.

At the end of this process, the total hectares burned for each protection zone and vegetation type were calculated and reported according to the vegetation map of the ANP in Table 1.

As evidenced by the 33 vegetation-covered land-use types in Table 1 (Camerieri et al. 2002), the area is of great natural importance due to the high heterogeneity of its natural forest flora, as a function of altitude gradient, aspect, and biodiversity, ultimately leading to a rich supply of ESs.

2.3 | Economic Approach to the Evaluation of ES Damaged

Considering the characteristics of the fire-affected study area, six ESs were selected for damage quantification. To estimate the economic impact of the fire-induced loss or reduction of these functions, an analytical procedure employing several economic evaluation methods was implemented (Table 2).

A discount rate (r) for the estimation formulas, consistent with comparable research, is assumed to range from 2% to 5%. Ciancio et al. (2007) observed higher values for more productive forests on fertile soils due to greater commercial yields. According to Grilli et al. (2017), this study employs a 2% discount rate.

Table 3 below presents the damage functions associated with the EEs lost in this case study, along with their corresponding evaluation methods as detailed in the formula. A full and detailed explanation of the monetary valuation methods used is provided in the following paragraphs.

2.3.1 | Wood Products

Fire's evident damage is total/partial destruction of trees, impacting the amount of wood provision. The event's involuntary nature demands a specific assessment (Carbone 2021). This involves considering specific property characteristics (common, recurrent, or exceptional) within a similar context. Some authors (Carbone 2005; Corona et al. 2022) suggest estimating fire damage to forests using the most probable complementary value, determined by the most probable cost, replacement, or transformation value in "no damage" and "damaged" states.

Complementary value also considers indirect aspects for unaffected parties. It compares the pre-damage system (H_0) (benefit/loss flows) with the post-damage system (H_1) (subsequent benefit/loss flows). The difference between these systems represents the complementary value corresponding to the damage (D) (Equations 1–3; Table 3).

Forest damage can be categorized into four types based on extent and duration: permanent total, temporary total, and permanent partial damage. The present study area has experienced temporary total damage.

TABLE 1 | Area covered by fire for each land-use type and corresponding code.

Code	Type of land use	Surface area covered by fire (ha)
1120	Galio irsuti-Fagetum forest	3.90
1141	Southern oak forest interspersed with aspects of degradation	25.38
1171	Natural Calabrian pine forest	252.92
1172	Natural Calabrian pine forest interspersed with aspects of degradation	185.41
1220	Congested oak forest	8.70
1221	Congested oak forest mixed with degradation aspects	2.72
1240	Chestnut forest	38.00
1310	Teucrio-Quercetim ilicis forest	1.35
1311	Teucrio-Quercetim ilicis forest with aspects of degradation	8.58
2110	Scented broom shrubland	574.50
2111	Shrubland with fragrant broom mixed with subnitrophilous pasture	307.85
2121	Shrubland with charcoal broom mixed with mountain pasture	1.07
2220	Arboreal spurge scrub	37.63
2221	Arboreal spurge scrub mixed with steppe grassland	1.16
2310	Garrigue with cysts	35.26
2330	Garrigue with cysts and calycotomes	25.05
3100	Mountain pasture	193.30
3210	Steppe grassland with cysts	18.72
3240	Mediterranean subnitrophilous arid pasture	97.76
3241	Subnitrophilous Mediterranean dry pasture	4.60
4110	Black alder riparian forest	10.54
4140	Pioneer glareicola vegetation	0.03
4141	Summer vegetation of pebbly riverbeds	19.58
5110	Mediterranean arable land	17.63
5120	Temperate belt arable land	13.93
5121	Temperate zone wooded arable land	1.05
5210	Olive grove	53.43
5230	Orchard	11.91
5240	Mixed cropping systems	54.05
5310	Coniferous reforestation of the hill and sub-mountain belt	29.84
5320	Mountainous coniferous reforestation with a predominance of Calabrian pine	291.35
5321	Mixed deciduous and coniferous reforestation of the mountain belt	15.82
5322	Reforestation of the mountain belt with broad-leaved trees (Neapolitan alder, walnut, cherry)	11.06
6110	Urban center	2.28
6140	Area with sparse or absent vegetation, landslide, severely eroded area	135.31

Source: Authors' QGIS elaborations.

The economic damage from destroyed wood products is divided into: Emerging damage (ED) and loss of income in growing stock replenishment (LISR) (Equation 4; Table 3). ED was calculated based on the harvestable wood volume at the time of the damage. This volume was determined using the "Prescrizioni di Massima e Polizia Forestale" (Calabria Region 2008) (see Tables S2 and S3) and multiplied by the current market price per m^3 (ISTAT 2023), net of extraction costs (Equation 5; Table 3).

LISR represents the foregone profit from timber sales until the pre-firewood stock is restored (minimum supply). This loss was estimated by considering the potential profit over multiple cutting cycles, net of harvesting and forest management costs (Equation 6; Table 3). Quantifying the total damage requires data on the affected area, tree species, wood volume, sale price, and extraction costs.

Forest location data is readily available through cartography. However, woody biomass volume requires precise field surveys using GIS. Average wood prices can be found in forestry administration territorial data, while market prices were extracted from ISTAT (2023). For coppice forests, only the firewood price was considered, while for other formations, the prevailing assortment type was considered.

Cutting and transportation costs were estimated parametrically, considering slope and distance to damaged wood. According to Ciancio et al. (2007) and real data collected, standardized costs are as follows: 15 €/m^3 (slope < 20%, distance < 300 m); 20 €/m^3 (slope 20%–35% and distance < 300 m or slope < 20% and distance 300–2500 m); 35 €/m^3 (slope > 35%, cable extraction).

TABLE 2 | ES selected for the study area and economic evaluation method adopted.

Ecosystem Services	Economic evaluation	Surface considered in the study (ha)
Wood production	Wood lost (restoration time)	Real: 517.72 Potential: 479.68
Production of non-wood forest products: mushrooms, oregano, and pasture grazing	Non-wood forest product value	1187.98
Provision of tourist and recreational services	Visit/tour cost	2394.08
Hydrogeological protection by reducing landslides, erosion, and runoff	Natural engineering work cost	1687.69
Climate change protection	Carbon credit value	1782.48
Protection of biodiversity or naturalistic function	Planting cost (naturalness, years at damage)	1807.78

Distances over 2500 m incur prohibitive costs. Estimation for ANP Zones B–D (Table S4) was conducted. Despite the legal ban on deforestation in Zone A (art. 32, para. 3 of ANP Regulation 2024) (MATTM 2016), damage was also calculated for this area (for completeness) but was excluded from the total damage assessment.

Affected tree species volumes were analytically estimated (Morizzi 2022) using surveys from similar south-southeast facing areas at 1150–1500 m asl, employing 13 m radius circular plots. For surviving trees, diameter, total height, and crown insertion height were measured. Plant counts (or stump counts for destroyed trees) were recorded. Volume was calculated by multiplying the basimetric area (diameter at 1.30 m), tree height, and a reduction coefficient. Income loss during growing stock reconstitution was estimated from the emergent damage's extractable quantity and the damaged species' current annual increment (Gasparini et al. 2022). This reconstitution period was divided into shifts according to the Calabria Region's (2008) prescriptions. Ordinary forest care and management costs that would have occurred without the fire were subtracted from the restoration period's damage estimate.

2.3.2 | Non-Wood Forest Products (NWFPs)

FAO (1995) defines NWFPs as tangible, biologically derived goods from forests, excluding wood. This includes diverse plant and animal products like fruits, mushrooms, herbs, spices, game, fibers (for construction, clothing, etc.), resins, and rubbers. Globally, NWFPs are a significant source of income, contributing 10%–60% of household income in some regions (Asfaw et al. 2013; Jensen 2009). They also mitigate seasonal food scarcity and hold cultural importance (Lovrić et al. 2020).

According to Ciancio et al.'s (2007) methodology, the burned area's NWFPs' productive capacity is temporarily reduced, and the damage is estimated as a multi-year, initial accumulation, as per Equation (6) (Table 3).

Literature on NWFPs restoration time varies greatly due to area-specific factors and fire type. Beyond visible damage, forest fires alter soil characteristics (Duguy et al. 2007), including microbial biomass, organic matter, and nutrient availability. A study by Guénon et al. (2013) suggests prefire forest conditions can take up to 17 years to restore.

Plant species restoration time depends on fire extent, seed propagation, moisture, soil fertility, and landscape variability (Fernández-Guisuraga et al. 2023). Animal species not only suffer direct fire impacts but also habitat alterations affecting food, shelter, competition and predation (Engstrom 2010). Prefire extinction risk and population size also influence recovery (Webb et al. 2023). Ensbey et al. (2023) found faster recovery for species with short generation times and vegetarian diets compared to those with long generation times and carnivorous diets. Due to a lack of specific studies for the study area, the Italian legal standard of 10 years postfire was considered for NWFPs nonuse (Law no. 353/2000).

2.3.3 | Recreational Activities

Estimating the tourist-recreational value after fires should consider the nonuse of forest for informal recreation (camping and walking), sports (hiking and cross-country skiing), nature observation, esthetic appreciation, and relaxation. Forest recreational functions are vital for modern quality of life (Riccioli et al. 2019; Bruzzese et al. 2022). However, the absence of a clear market for these benefits/public goods significantly hinders determining the marginal values of forest attributes (Scarpa et al. 2000). Several methods exist to monetize recreational tourism value, including indirect approaches like travel cost (Borzykowski et al. 2017) and hedonic price (Hunt et al. 2005), and direct methods such as park entrance fees (Silvestro et al. 2021). This study employs a direct method by analyzing prefire visit numbers and the average visit value. Given the reduced tourist appeal of the affected areas for several years, the damage is estimated as a multi-year initial accumulation, as shown in Equation (8) (Table 3).

2.3.4 | Hunting Activities

The prohibition (or cessation) of hunting leads to economic damage quantifiable via two methods: (1) annual willingness to pay (WTP) per hunter (Román et al. 2013); (2) the average cost of Territorial Hunting Area (THA) enrollment, THA surface area, and the number of enrolled hunters (Ciancio et al. 2007). The estimation mirrors that for NWFPs damages (Equation 9; Table 3). The hunting ban period is assumed to be 10 years (art 10(1) Law no. 353/2000).

2.3.5 | Hydrogeological Protection

Hydrogeological protection, as ES influencing freshwater flow (Moghadam et al. 2024), is threatened by soil loss and erosion, a major environmental issue, especially in Mediterranean/arid regions, due to vegetation removal and soil organic matter depletion (Leys et al. 2024; Roshan and Biswas 2023). Fire-produced ash further exacerbates this by creating a hydrophobic soil coating, reducing moisture and infiltration, thus increasing runoff and erodibility (Bombino et al. 2023). Vegetation's role in erosion control is vital; roots bind soil, and foliage intercepts rainfall (Fernández-Raga et al. 2017), a subject of much research (Merlo and Croitoru 2005; Grilli et al. 2017). Bernetti et al. (2013) classify methodological approaches to value this protection: (i) *cost of avoiding disaster damage*: valuing the potential damage prevented by hydrological protection; (ii) *subrogation value*: the cost of interventions needed to replace the protective function of forest cover in fire-prone areas; this includes one-off greening costs and annual maintenance for the time needed to restore the area's regulation capacity (Ciancio et al. 2007). Equation (10) (Table 3) was adopted to estimate the protection function.

TABLE 3 | Monetary quantification approaches.

ESs	Equation	Formula	Description
Wood production	(1)	$D = H_0 - H_1$	[*R*] and [*C*] revenues and costs of the pre-damage (H_0) and post-damage (H_1) scenarios; [*n*] damage time; [*i*] years since the damage occurred; [*t*] a generic year where the previous state is restored without damage; $\frac{1}{q^i}$ discount factor to adjust the different monetary values at time [*n*].
	(2)	$H_0 = \left[\sum_{i \to n}^{t} \left(R_{0,i} - C_{0,i}\right) \times \frac{1}{q^i}\right]$	
	(3)	$H_1 = \left[\sum_{i \to n}^{t} \left(R_{1,i} - C_{1,i}\right) \times \frac{1}{q^i}\right]$	
	(4)	$D_{wp} = E_D + \left[\left[\sum_{2021}^{n} L_{ISR} + Cc\right] - \sum_{2021}^{n} Me\right]$	D_{wp} = wood production damage; ED = emerging damage; LISR = income loss in the growing stock replenishment (period 2021 − *n*); Cc = crop care for the first year after planting or recovery; Me = management expenses.
	(5)	$ED = (Pl - Cl) \times V \times Surf$	Pl = wood price at landing; Cl = logging cost; V = volume; Surf = fire-affected surface.
	(6)	$L_{ISR} = \left[[(Pl - Cl) \times V \times Surf] \times \frac{q^{nt}-1}{q^t-1} \times \frac{1}{q^{nt}} + Cc\frac{1}{q^n}\right] - Me \times \frac{q^{n2}-1}{r \times q^{n2}}$	*n* = shifts number; t = shift years; *r* = discount rate; nt = years; n2 = years to replenish the woody provision.
NWFPs	(7)	$ED_{NWFPs} = Surf_{NWFPs} \times R_{NWFPs} \times \frac{(1+r)^p - 1}{r \times (1+r)^p}$	ED_{NWFPs} = environmental damage from NWFPs loss (€); $Surf_{NWFPs}$ = fire-affected surface with NWFPs production capacity (ha); R_{NWFPs} = average annual yield of NWFPs production (€/ha); *r* = discount rate; *p* = years of non-harvesting of NWFPs after fire.
Recreational activities	(8)	$ED_{rec} = V_{rec} \times N_{rec} \times \frac{(1+r)^g - 1}{r \times (1+r)^g}$	ED_{rec} = environmental damage from the loss of tourist-recreational activities (€); V_{rec} = average visit value before fire (€); N_{rec} = average visits number per year; *r* = discount rate; g = years of no tourist-recreational activity after fire.
Hunting activities	(9)	$ED_{hunt} = Surf_{hunt} \times R_{hunt} \times \frac{(1+r)^v - 1}{r \times (1+r)^v}$	ED_{hunt} = environmental damage from reduced hunting activity (€); $Surf_{hunt}$ = fire-affected surface used for hunting activity (ha); R_{hunt} = average annual return from hunting activity (€/ha); *r* = discount rate; v = years of no hunting activity after fire.
Hydrogeological protection	(10)	$ED_{hydr} = Surf_{prot} \times \left(C_{green} + C_{am} \times \frac{(1+r)^i - 1}{r \times (1+r)^i}\right)$	ED_{hydr} = environmental damage from reduced hydraulic protection activity (€); $Surf_{prot}$ = fire-affected surface with protective functions (ha); C_{green} = greening cost (€/ha); C_{am} = annual maintenance cost of the greened area (€/ha); *r* = discount rate; i = years of green intervention.

(Continues)

TABLE 3 | (Continued)

ESs	Equation	Formula	Description
Climate change protection	(11)	$ED_c = Surf \times Vol_b \times BEF \times 0.5 \times P_C$	ED_c = environmental damage from carbon dioxide emissions into the atmosphere (€); Surf = fire-affected forest surface (ha); Vol_b = volume of wood mass entirely burnt (m^3/ha); BEF = Biomass Expansion Factor (coefficient of transformation from volume of wood mass, expressed in m^3, to epigeous tree biomass, expressed in tonnes of dry matter); 0.5 = coefficient of transformation from biomass (dry matter) to carbon; P_C = price for a tonne of carbon dioxide (€/t).
Naturalistic value	(12)	$ED_{nat} = C_n \times Surf \times LD \times C_p \times (1+r)^n$	ED_{nat} = naturalistic damage (€); 0.5 = multiplication coefficient; Surf = fire-affected surface (ha); LD = fire damage level; C_p = planting cost (€/ha); r = discount rate; n = number of years needed for reconstruction.

The extent of the fire-affected protective area is determined by slope gradient, establishing a minimum threshold where erosion and instability damage are negligible. Slope dictates the appropriate intervention and its cost (Ciancio et al. 2007): < 40%: negligible damage; 40%–70%: damage typically requiring extensive interventions (e.g., boulder consolidation and grassing); > 70%: damage typically requiring intensive interventions (e.g., steps, planting cuttings, drainage, and gullies).

2.3.6 | Climate Change Protection

Forests play a crucial role in climate stabilization by absorbing atmospheric carbon and converting it to biomass (Penman et al. 2003; JRC 2023; Roebroek et al. 2023). However, biomass and organic matter combustion releases carbon dioxide, increasing greenhouse gas concentrations (Silvestro et al. 2021). The economic impact of these emissions can be assessed using the market value of carbon allowances. Following IPCC guidelines (Penman et al. 2003; Federici et al. 2008), carbon quantity is estimated by multiplying wood volume (cormometric/dendrometric mass) by a biomass expansion factor (BEF), specific to vegetation type. The resulting biomass is then multiplied by the commercial price of carbon per ton, as in Grilli et al. (2017), to calculate the damage to this ES (Equation 11; Table 3).

2.3.7 | Naturalistic Value

The "naturalistic value" of biodiversity—including genetic, species, and ecosystem diversity, and its future availability (Taye et al. 2021; Turner et al. 2007)—is a challenging ES to monetize due to biodiversity's inherent functions and limited human utilization in pristine, biodiverse habitats (Carrasco et al. 2014). To quantify damage to this ES, the reconstruction cost of lost species was employed (Ciancio et al. 2007; Pettenella et al. 2008), weighted by their lifespan at the time of damage and a natural gradient coefficient (C_n). This coefficient (0–1, high naturalness) reflects the likelihood of finding key structural attributes in various forest types: vertical stratification, native species, high average age, tree species number, diverse development stages, abundant woody necromass, and habitat trees. The calculation for this ES's value is provided in Equation (12) (Table 3).

3 | Results and Discussion

3.1 | Wood Production

To achieve a precise estimation of the damage, the different forest categories were considered, and the estimate for each category was determined through the application of specific variables.

As evidenced in Table S5, the variables and associated damage estimates for Zones B–D indicate that the actual damage amounts to €1,506,938.84. Furthermore, there is an additional cost of €3,751,255.22, attributed to lost mowing shifts in the years following the fire, and €940,763.93 for maintenance expenditures in the initial year postfire, net of annual operating costs. Consequently, the total estimated damage for these zones is calculated at €5,139,252.00. Table S6 details the potential damage in Zone A, with an estimated actual damage of €1,353,520.76, in addition to €3,454,660.89 for lost shifts in the subsequent years and €875,350.35 for maintenance in the first year after the fire. Subtracting the annual operating costs from the summation of these values yields a total damage of €4,713,044.06.

3.2 | NWFPs

In this case study, field analysis revealed that the estimation of NWFPs encompasses mushrooms, oregano, and pasture grazing. Subsequent to the estimation of the average yield of these products within the fire-affected areas, the quantification of the damage is performed by discounting the value of the potential production that would have been realized in the absence of the fire, commencing from the time of the incident. Regarding mushrooms, after identifying the eligible areas and excluding those deemed inaccessible (Table S7) and considering the relevant specific variables (prices and quantities) as detailed in Table S8, a total damage of €320,133.51 was determined over a 10-year period of non-harvesting.

The selection of suitable areas for oregano cultivation was based on the chemical and physical characteristics of the soil, including pH, typical habitat, and accessibility, as outlined in Table S9. Based on the variables presented in Table S10, the total damage resulting from the non-harvesting of oregano over a 10-year period was calculated to be €415,953.35.

Concerning the damage to pasture, it is noted that the area of pasture affected by fire in this case study amounts to 769.81 ha. The average yield of biomass production suitable for grazing was determined using data from the Agricultural Accountancy Data Network (RICA 2022), which provides annual figures for Italy with regional specificity by detailing the principal economic indices on an annual basis for each crop. In this specific instance, the average annual yield of biomass production usable for grazing was obtained by taking the average gross saleable production (GSP) of the categories "Unproductive pasture" and "Permanent pasture" and subtracting the average specific costs calculated for each category (S10). The total loss attributed to pasture degradation over a decade amounts to €1,382,983.93.

3.3 | Recreational Tourism

The assessment of damage to the tourism-recreational function in this study refers to the average number of visits per year observed before the fire and the mean economic value associated with each visit. The fire-affected area is characterized by an extensive network of trails that afford visitors the opportunity to appreciate its diverse and compelling natural attributes. Moreover, the ANP's designation, in 2021, as one of the 11 Italian parks within the UNESCO Global Network of Geoparks, highlights its inherent value. Records from key regional promotion associations indicate a significant volume of tourist excursions in the study area (Table S12). Starting from an average total value of €2600 in the years 2018 and 2019, a discernible reduction occurred in 2020 due to the implementation of COVID-19 pandemic regulations, culminating in a complete absence of visits in 2021 as a consequence of the fire. Data derived from singular interviews reveal that 130 hikers and walkers participated in excursions and guided tours during the 2018–2019 period, with a mean individual expenditure of €20. Consequently, the total estimated damage to the tourism-recreational function, assuming a 15-year period of non-operationality, amounts to €33,408.09 (Table S13). Nevertheless, this timeframe may underestimate the recovery period, considering the impact of the century-old trees on the tourism appeal and the potentially extended period required for visitor interest to return. Conversely, the restoration of trail usability and visitor appreciation may not be entirely dependent on the complete recovery of the vegetation landscape to its prefire condition.

3.4 | Hydrogeological Protection

This ES value is determined using a surrogate cost approach, which considers the expenses required for revegetation efforts in fire-damaged areas with a critical hydrogeological protection function. The cost of revegetation comprises two key components: the expense of planting appropriate species, including naturalistic engineering works, and the annual maintenance costs necessary over a variable period to restore the prefire hydrogeological protection function. To account for the varying degrees of slope within the fire-affected area, it was essential to delineate the area falling into each slope class (Table S14). Areas with slopes less than 40% were excluded from this assessment.

The revegetation cost is estimated at €12,000.00/ha for areas with slopes exceeding 70%, reflecting the extensive naturalistic engineering work required to stabilize the slopes and the subsequent planting of suitable species (see Table S15 for detailed breakdown). For areas with slopes ranging between 40% and 70%, the cost is €5000.00/ha.

The total estimated cost value for hydrogeological protection, encompassing both the revegetation costs and the maintenance expenses for the initial 2 years following planting, amounts to €10,555,436.24.

3.5 | Climate Change Protection

The estimation of damage related to climate change mitigation considers the role of forest species in storing atmospheric carbon through conversion into biomass, and this function has been evaluated by assessing the carbon stock destroyed by the fire and applying an appropriate price per ton of carbon. Due to the volatile European carbon market (ranging from €16.00/tonne in 2018 to €103.00/tonne in 2022) (Rickels et al. 2022) and considering potential COVID-19-related speculation (Ghosh et al. 2022), a conservative price of €20.00/tonne was assumed. This resulted in an estimated damage of €4,379,435.65 ha for the 860.25 ha affected (Table S16), considering only the carbon loss in the topsoil as tree roots were unharmed.

3.6 | Naturalistic Value

The naturalistic value was determined using the cost for replanting species adjusted by their coefficient of naturalness (C_n). The total estimated damage related to the naturalistic function amounts to €4,522,988.18 (Table S17).

3.7 | Total Economic Damage

The total estimated loss in terms of ES resulting from fires in the analyzed ANP area during the year 2021 amounts to €26.7 million (as detailed in Table 4), with an average loss of €10.7 thousand per hectare.

Among the analyzed ESS, hydrogeological protection presents the most significant percentage incidence, approaching 39.5% (as detailed in Table 4). This is closely followed in terms of incidence by wood production at 19.2%, the naturalistic function at 16.9%, and subsequently by protection against climate change. Concerning wood production, the reported figures

TABLE 4 | Partial and total monetization of the value of ES lost.

Ecosystem service		Total value (€)	Percentage distribution (%)	Average value (€/ha)
Wood products		5,127,832.41	19.2	2057.86
NWFPs	Mushrooms	320,133.51	7.9	128.47
	Oregano	415,953.35		166.93
	Pasture for grazing	1,382,983.93		555.01
Recreational tourism		33,408.09	0.1	13.41
Hydrogeological protection		10,555,436.25	39.5	4236.02
Protection against climate change		4,379,435.65	16.4	1757.52
Naturalistic function		4,522,988.18	16.9	1815.13
Total		**26,738,171.36**		**10,730.34**

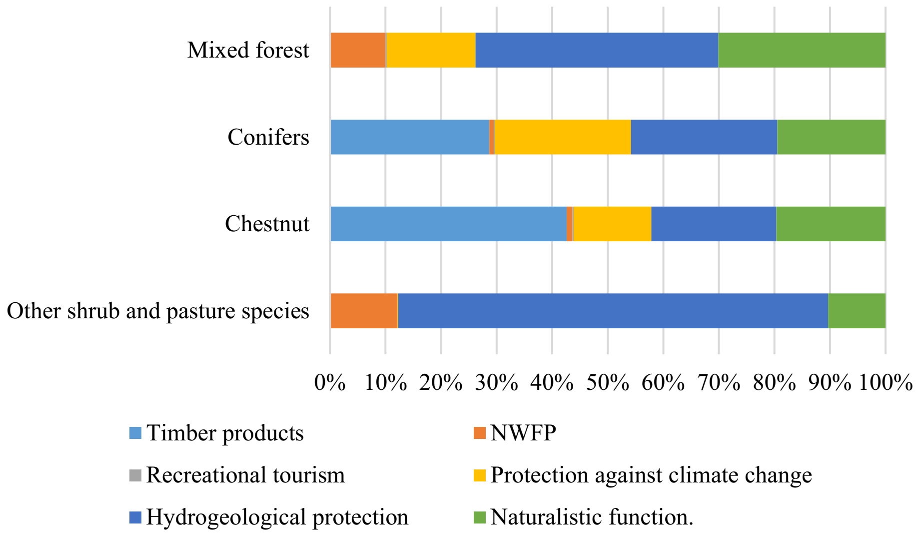

FIGURE 4 | Percentage distribution of ES damage value for forest types. [Colour figure can be viewed at wileyonlinelibrary.com]

specifically concern the valuation of wood mass within those areas of the ANP where harvesting is permitted, thereby excluding Zone A.

The lowest levels of incidence are noted for NWFPs, accounting for 7.9% overall, within which the ES of pasture grazing holds the highest individual value. Finally, the ES connected to recreational tourism exhibits the smallest incidence, recorded at 0.1%.

As depicted in Figure 4, the percentage distributions of the economic value associated with the different ESs exhibit notable variations. These distributions are organized based on forest type and further consolidated into the overarching macro-categories: "Mixed forest," "Coniferous," "Chestnut," and "Other shrub and pasture species."

The initial typology indicated that hydrogeological protection is the most prevalent ESs, accounting for 44%, followed by nature function (30%), climate change mitigation through carbon sequestration (16%), and NWFPs at 10%. Given that wood extraction is concentrated in Zone A of the park and thus not feasible in this area, this ES was not calculated. For coniferous species, wood production exhibits the highest incidence (29%), followed by hydrogeological protection (25%) and climate change protection (24%). For the chestnut category, wood production is the most frequent ES (43%), followed by hydrogeological protection (22%) and nature value (20%). In the last grouping, "Other shrub and pasture species," hydrogeological protection demonstrated the highest value at 77%, with NWFPs following at 12%. A significant percentage of hydrogeological protection is correlated with the slope gradient. NWFPs such as mushrooms, oregano, and pastures show a higher incidence in areas lacking highly specialized forest types for wood production, such as pine or chestnut forests. The recreational tourism ES exhibits a low incidence across the considered individual types, as the estimated economic loss due to fire is distributed over almost the entire affected area, given that tourist routes and interest in their use are associated with the opportunity to experience different forest environments. This study highlights that the economic benefits of forest ecosystems stem from their unique attributes (Taye et al. 2021). These inherent characteristics necessitate tailored evaluation methods (Carbone 2021). Consequently, the distinct nature of our findings makes direct comparisons with the limited existing literature challenging.

Regarding forest fire damage, a notable parallel exists with the study of Silvestro et al. (2021), even if in another Italian region, which reported similar economic damage related to woody assortments (€2711.61/ha) in broadleaf forests with moderate to high burn severity. While Grilli et al.'s (2017) analysis of fire damage to ESs in Slovenia's Triglav National Park yielded lower economic values due to local variables and pricing, the ranking of damage by economic quantification mirrors our findings: hydrogeological protection ranked highest, followed by wood production and carbon credits. The prominence of hydrogeological protection also aligns with the study by Brun and Paletto (2003), which, although focused on calculating the TEV of a forested area in Piedmont (northern Italy) rather than fire damage, employed a similar estimation procedure. Concerning the distribution of value across different ESs and forest types, Bernetti et al.'s (2013) TEV study in Tuscany forests similarly found the highest value associated with wood production in coniferous forests, with other ESs, such as those related to NWFPs, being comparatively less significant.

3.8 | Estimated Potential Cost of Prevention

Forest fire research consistently demonstrates that thoughtful forest management, focused on reducing live and dead surface fuels and creating fuel discontinuity, significantly mitigates fire spread and intensity. This principle is corroborated by global data, such as that compiled in the World Overview of Conservation Approaches and Technologies (WOCAT) database (Schwilch et al. 2012), which documents sustainable land management practices, and by numerous scientific publications (Rothermel and Philpot 1973; Agee and Skinner 2005; Johnson 2007). Scientific inquiry remains highly active in proposing silvicultural solutions to limit fire propagation. For instance, Piqué et al. (2022), in a study conducted in a typically Mediterranean climate zone of Spain, reported significant success in reducing fire damage when thinning and undergrowth management are implemented to decrease fuel loads and break the vertical and horizontal continuity of vegetation. Marziliano et al. (2024), focusing on the same geographical area, instead investigated silvicultural techniques to disrupt the vertical and horizontal fuel continuity in pine stands. Jucker Riva et al. (2016), specifically addressing Mediterranean forests, advocate for fuel break creation and fuel management strategies to interrupt continuity. Thompson et al. (2022) and Carrasco et al. (2025) further explored these solutions, demonstrating that optimal results in reducing fire spread can be achieved even when fuel break areas cover only 2.5%–5% of the total surface, provided that their spatial allocation is specific and strategic.

Assuming the implementation of specific silvicultural interventions and the creation of fuel breaks within the study area, we quantified the projected annual expenditure using data from the Agricultural and Forestry Price List of the Calabria Region (2022).

The cost for understory cleaning in a forest with a low presence of invasive species is approximately €344.40/ha, while the annual maintenance of a fuel break is set at €1800/ha. To determine the annual fuel break maintenance cost, it was assumed that 2.5% of the total burnt area (2157.1 ha) is dedicated to fuel breaks, corresponding to 53.93 ha. Multiplying this area by the maintenance cost of €1800/ha results in an annual expenditure of €97,069.50. Estimating the cost of understory cleaning is more complex, as the presence of invasive species is strongly linked to the light intensity characteristics of specific forest types. Literature suggests varying optimal intervals: Molina et al. (2021) reported positive effects in pine forests for up to 4 years after prescribed fire, while Castro et al. (2022) highlighted efficacy after 24 months. Adopting a biennial cleaning cycle with annual surface alternation (i.e., cleaning half the area each year), the total annual cost for understory cleaning is projected at €171,752.28. Consequently, the sum of these two components indicates a total projected annual expenditure for fire mitigation in the area of €268,821.78.

4 | Conclusions

To address the research question of this study—What is the economic impact of fire-induced loss or damage to each ES?—remote sensing and on-site survey data for detailed analysis were used. It is important to highlight that the remotely sensed data used in this study for burnt area detection (i.e., EFFIS burnt area database) are derived from MODIS satellite imagery with a resolution of 250 m and then refined with visual interpretation of 20 m resolution Sentinel-2 satellite images. This spatial resolution may lead to an overestimation of the actual burnt area due to the possible presence of small unburnt areas within the boundaries of the detected burnt ones. The retrieved burnt areas enabled the quantification of the economic value of each ES, totaling €26.7 million in damage for the studied area. The monetary valuation of each ES followed the zoning regulations of the ANP. For instance, the estimated wood volume in the non-harvesting Zone A was excluded from the final calculation, as this restriction is due to adjustable legislative factors, not permanent physical attributes like slopes. The analysis identified key variables significantly influencing damage to specific ESs: trees' age for wood production; terrain characteristics (species, slope, and soil) for NWFPs; terrain slope for hydrogeological services; wood biomass quantity for climate change protection; visitation numbers for recreational tourism; and ecosystem biodiversity for naturalistic value.

Monetizing the value of the ESs, also highlighted the significance of those often less tangible to the public and not readily assigned an economic value, such as climate protection and naturalistic values.

About the second question—How does this economic value fluctuate following the intrinsic characteristics of forest ES?—the analysis revealed a differential economic value associated with damaged ESs across different forest types, underscoring the unique nature of ecosystems. The results demonstrate the functional diversity of environments, indicating that even seemingly simpler systems, like "Other shrub and pasture species," possess a perceivable intrinsic economic value through their functions, including those related to NWFPs, and can contribute to the income of mountain communities.

While this study offers valuable insights into the area's ecological and economic aspects, it is important to acknowledge certain inherent limitations. For instance, the lack of a comprehensive visitors' census means our assessment of recreational tourism value might be a conservative estimate, as it primarily relied on excursion association data. The open accessibility of the area suggests potentially higher visitor numbers, including those engaging in activities beyond organized hikes, such as the full spectrum of tourism-recreational activities, such as outdoor picnics, which were particularly widespread in the study area before the fire. Furthermore, the long-standing presence of centuries-old trees before the fire highlights that the projected 15-year timeframe for new vegetation to become touristically appealing could be a shorter-term perspective. Similarly, the lack of specific studies on this area of NWFP's recovery suggests that the 10-year period referenced, based on broader Italian regulations, might not fully capture the recovery needs of all components, such as huntable wildlife. Moreover, it is also critical to contextualize these findings within the broader challenges of increasing drought and global temperatures, which are projected to exacerbate forest fire risks in the Mediterranean region and even extend to central Europe (Arias et al. 2021; El Garroussi et al. 2024). Other ES, such as water regulation and soil fertility, although present in the forest, were not considered in this study because primary data were unavailable.

Among other potential ES, the pollination was excluded as there are no highly specific crops in the area that could have been affected by the damage. A different approach was adopted by Silvestro et al. (2021), who were able to incorporate this service into their analysis due to a documented reduction in the yield of Vesuvian tomatoes, caused by a fire that occurred in that territory. The adoption of the TEV approach is warranted because this methodology facilitates a more aggregate and conceptually coherent valuation of total losses compared to alternative tools for ES estimation. This methodological choice was enabled by the precise and timely availability of primary data, specifically those pertaining to wood volume per hectare, slopes, and non-timber forest products. Conversely, reliance on generic modeling instruments, such as InVEST (Natural Capital Project 2024), was deemed less effective due to inherent limitations concerning the punctual and accurate accounting of fire damage. These tools primarily rely on climatic and geospatial data, often resulting in the oversimplification of ecosystem dynamics. For example, specific inter-service interactions (such as vegetation's role in regulating hydrology and climate) may be excessively simplified. Notably, the models employ simple equations and restricted parameters for the estimation of water-related ESs, a simplification that can compromise quantification accuracy in complex environments (Anjinho et al. 2022). Furthermore, regarding productive value, as highlighted in the InVEST user guide itself, the tool fails to capture productivity data influenced by non-climatic variables, such as management practices. Consequently, it is unable to register the variation in productivity that occurs across heterogeneous landscapes (Natural Capital Project 2025). For instance, a rocky hillside and a fertile river valley, sharing identical climatic conditions, would yield the same predicted output in the current model. These deficiencies underscore the necessity of relying on primary data and the TEV framework to ensure the fidelity and precision required for damage estimation.

Recognizing this, rigorous and robust scientific research becomes essential for informing effective development and land protection strategies (Spada et al. 2022). The results derived from this study, strengthened by its methodological approaches, represent a valuable suggestion for policymakers aiming to conserve natural resources, mitigate climate change, and acknowledge the productive capacity of forests (Spada et al. 2025).

Addressing fire impact requires integrated approaches, including targeted mapping, resilience-building silvicultural practices, and supportive environmental policies to manage restoration costs and optimize the benefits from natural ESs (G. De Luca et al. 2022; Marziliano et al. 2024; Pettenella et al. 2008).

Ultimately, increasing public and policymakers' awareness of the economic significance of environmental assets and the losses from fire is key to encouraging protective behavior.

While cherishing that precise, universal estimations are challenging due to the resource specificity and valuation subjectivity, studies like this provide a crucial reference point for decision-makers facing immediate choices. Given the fundamental importance and uniqueness of the environment in question, these timely decisions could have the potential to irreversibly determine the long-term availability of these vital resources for both humanity and the wider ecological communities.

Author Contributions

Emanuele Spada: conceptualization, data curation, formal analysis, investigation, methodology, visualization, writing – original draft, writing – review and editing. **Giacomo Falcone:** conceptualization, data curation, formal analysis, methodology, visualization, writing – review and editing. **Salvatore Praticò:** data curation, investigation, validation, writing – review and editing. **Maria Carmela Benedetto:** data curation, investigation. **Giovanni Gulisano:** supervision, writing – review and editing. **Nathalie Iofrida:** conceptualization, data curation, investigation, methodology, writing – review and editing. **Anna Irene De Luca:** conceptualization, data curation, methodology, project administration, resources, supervision, validation, writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:** ESs of fire-affected areas subject to monetary valuation. **Table S2:** Minimum wood mass according to the prescriptions of the Calabria Region (2008). **Table S3:** Wood withdrawable by minimum wood mass class. *Source:* Calabria Region (2008). **Table S4:** Surface area for each forest type and distribution according to the different areas of the ANP and slope classes. **Table S5:** Variables considered in the study and estimation of real damage for the wood products (ANP Areas B–D). **Table S6:** Variables considered in the study and estimation of potential damage for the wood products (ANP Area A). **Table S7:** Determination of the useful area for estimating environmental damage from the loss of NFWP, based on park areas and slope classes: mushrooms. **Table S8:** Variables and damage estimation NWFPs: mushrooms. **Table S9:** Determination of the useful area for estimating environmental damage from the loss of NFWP, based on ANP areas and slope classes: oregano. **Table S10:** Variables and damage estimation NWFPs: oregano. **Table S11:** Variables and damage estimation NWFPs: pasture. **Table S12:** Variables and estimation of damage related to the tourism-recreational function. **Table S13:** Calculation of damage related to the tourism-recreational function. **Table S14:** Determination of the surface area with a protective function based on the slope and the species present before the fire. **Table S15:** Variables and estimated protection function on surface(s) with different slope classes considered. **Table S16:** Variables and estimated climate change protection function. **Table S17:** Variables and estimation function of naturalistic function.