Article:

Lecina-Diaz, Judit, Campos, Joao, Pais, Silvana et al. (18 more authors) (2023) Stakeholder perceptions of wildfire management strategies as nature-based solutions in two Iberian Biosphere Reserves. Ecology and Society. 39. ISSN 1708-3087

https://doi.org/10.5751/ES-13907-280139

Lecina-Diaz, J., J. C. Campos, S. Pais, C. Carvalho-Santos, J. C. Azevedo, P. Fernandes, J. F. Gonçalves, N. Aquilué, J. V. Roces-Díaz, M. Agrelo de la Torre, L. Brotons, M.-L. Chas-Amil, A. Lomba, A. Duane, F. Moreira, J. M. Touza, V. Hermoso, Â. Sil, J. R. Vicente, J. Honrado, and A. Regos. 2023. Stakeholder perceptions of wildfire management strategies as nature-based solutions in two Iberian biosphere reserves. Ecology and Society 28(1):39. https://doi.org/10.5751/ES-13907-280139

Research

Stakeholder perceptions of wildfire management strategies as nature-based solutions in two Iberian biosphere reserves

Judit Lecina-Diaz [1,2,3], *João C. Campos* [1,4], *Silvana Pais* [1,2,5], *Claudia Carvalho-Santos* [6], *João C. Azevedo* [7,8], *Paulo Fernandes* [9], *João F. Gonçalves* [1,2,5,10], *Núria Aquilué* [11], *José V. Roces-Díaz* [12], *María Agrelo de la Torre* [13], *Lluis Brotons* [11,14,15], *María-Luisa Chas-Amil* [16], *Angela Lomba* [1,2,5], *Andrea Duane* [11,17], *Francisco Moreira* [1,2], *Julia M. Touza* [18], *Virgilio Hermoso* [19], *Ângelo Sil* [1,2,7,8,9], *Joana R. Vicente* [1,2,5], *Joao Honrado* [1,2,5] and *Adrián Regos* [1,2,11,20]

ABSTRACT. Increased large and high-intensity wildfires cause large socioeconomic and ecological impacts, which demand improved landscape management approaches in which both ecological and societal dimensions are integrated. Engaging society in fire management requires a better understanding of stakeholder perceptions of wildfires and landscape management. We analyze stakeholder perceptions about wildfire-landscape interactions in abandoned rural landscapes of southern Europe, and how fire and the land should be managed to reduce wildfire hazard and ensure the long-term supply of ecosystem services in these fire-prone regions. To do so, a structured online questionnaire was sent to the stakeholders of two transboundary biosphere reserves in Spain-Portugal. Our analysis also questioned to what extent fuel management strategies can be considered nature-based solutions (NbS) using the IUCN standard. Overall, stakeholders state that fire should be managed and support fire prevention in lieu of fire suppression policies. Rural abandonment is perceived as the main cause of large wildfires, with high-intensity fires impacting the study regions more than in the recent past, a trend which they expect to continue in the future in the absence of management. All the suggested fuel management strategies, except chemical treatments, were accepted by the stakeholders who perceive more positive than negative effects of fuel management on forest ecosystem services. Transboundary coordination was rated as inadequate or even nonexistent. We did not find differences among stakeholder sectors and biosphere reserves, indicating that in the study area, there is a general agreement on perceptions about wildfire and associated impacts at the landscape level. Finally, we showed that promoting agricultural and livestock uses, modifying forest species composition to increase fire resistance, and introducing large herbivores have the potential to become effective NbS in the regions. This study represents a first-step analysis representing a base for future co-design and implementation of NbS to improve fuel management, contributing to the understanding of the stakeholder support for their application in addressing the socioeconomic challenges in high fire-risk areas.

Key Words: *biosphere reserves; ecosystem services; fuel management; landscape conservation; perceptions; Portugal-Spain; questionnaire; social-ecological systems; stakeholders*

INTRODUCTION

Worldwide, wildfires are one of the most common wildland disturbances (van Lierop et al. 2015, Bowman et al. 2017, Abatzoglou et al. 2018) affecting an annual average of 300-500 million hectares (Randerson et al. 2012, Giglio et al. 2018). In fire-prone regions, wildfires are an integral and critical driver of ecosystem dynamics (Turner 2010, Ding et al. 2012). However, changing fire regimes are increasingly causing more socioeconomic (e.g., people, infrastructure) and ecological impacts (e.g., soil erosion, climate mitigation potential, biodiversity; Pausas et al. 2008, Anderegg et al. 2020). Examples are the uncontrollable megafires that have recently occurred in California (between 2018 and 2021), the Australian Black Summer (2019, 2020), or extreme wildfires like the 2017 fires in Portugal and northwestern Spain, when more than one hundred people died (San-Miguel-Ayanz et al. 2020).

Society has co-evolved with fire over millennia (Moritz et al. 2014, Doerr and Santín 2016, Pausas and Keeley 2019). Historically, aboriginal and agricultural societies used fire across the globe for a range of livelihood- and cultural-related purposes. However, in Southern Europe, agricultural abandonment has been a common

[1]CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado, Campus de Vairão, Universidade do Porto, Portugal, [2]BIOPOLIS Program in Genomics, Biodiversity and Land Planning, CIBIO, Campus de Vairão, Vairão, Portugal, [3]Technical University of Munich, TUM School of Life Sciences, Ecosystem Dynamics and Forest Management Group, Freising, Germany, [4]CICGE, Centro de Investigação em Ciências Geo-Espaciais, Faculty of Sciences, University of Porto, Vila Nova de Gaia, Portugal, [5]Departamento de Biologia, Faculdade de Ciências, Universidade do Porto, Porto, Portugal, [6]Centre of Molecular and Environmental Biology (CBMA) & Institute for Bio-Sustainability (IB-S), University of Minho, Braga, Portugal, [7]Centro de Investigação de Montanha (CIMO), Instituto Politécnico de Bragança, Campus de Santa Apolónia, Bragança, Portugal, [8]Laboratório Associado para a Sustentabilidade e Tecnologia em Regiões de Montanha (SusTEC), Instituto Politécnico de Bragança, Campus de Santa Apolónia, Bragança, Portugal, [9]CITAB, Centro de Investigação e de Tecnologias Agro-Ambientais e Biológicas, Universidade de Trás-os-Montes e Alto Douro, Portugal, [10]proMetheus—Research Unit in Materials, Energy and Environment for Sustainability, Instituto Politécnico de Viana do Castelo (IPVC), Viana do Castelo, Portugal, [11]Centre de Ciència i Tecnologia Forestal de Catalunya (CTFC), Solsona, Spain, [12]SMartForest Research Group, Department of Biology of Organisms and Systems, Oviedo University, Mieres, Spain, [13]TRAGSATEC (Tecnologías y Servicios Agrarios, S.A., S.M.E., M.P), [14]CREAF, Cerdanyola del Vallès, Spain, [15]CSIC, Cerdanyola del Vallès, Spain, [16]Department of Quantitative Economics. Universidade de Santiago de Compostela, Santiago de Compostela, Spain, [17]Department of Agricultural and Forest Engineering, University of Lleida, Lleida, Spain, [18]Department of Environment and Geography and York Environmental Sustainability Institute, University of York, Heslington, York, UK, [19]Departamento de Biología Vegetal y Ecología, Universidad de Sevilla, Sevilla, Spain, [20]Departamento de Zooloxía, Xenética e Antropoloxía Física, Universidade de Santiago de Compostela, Santiago de Compostela, Spain

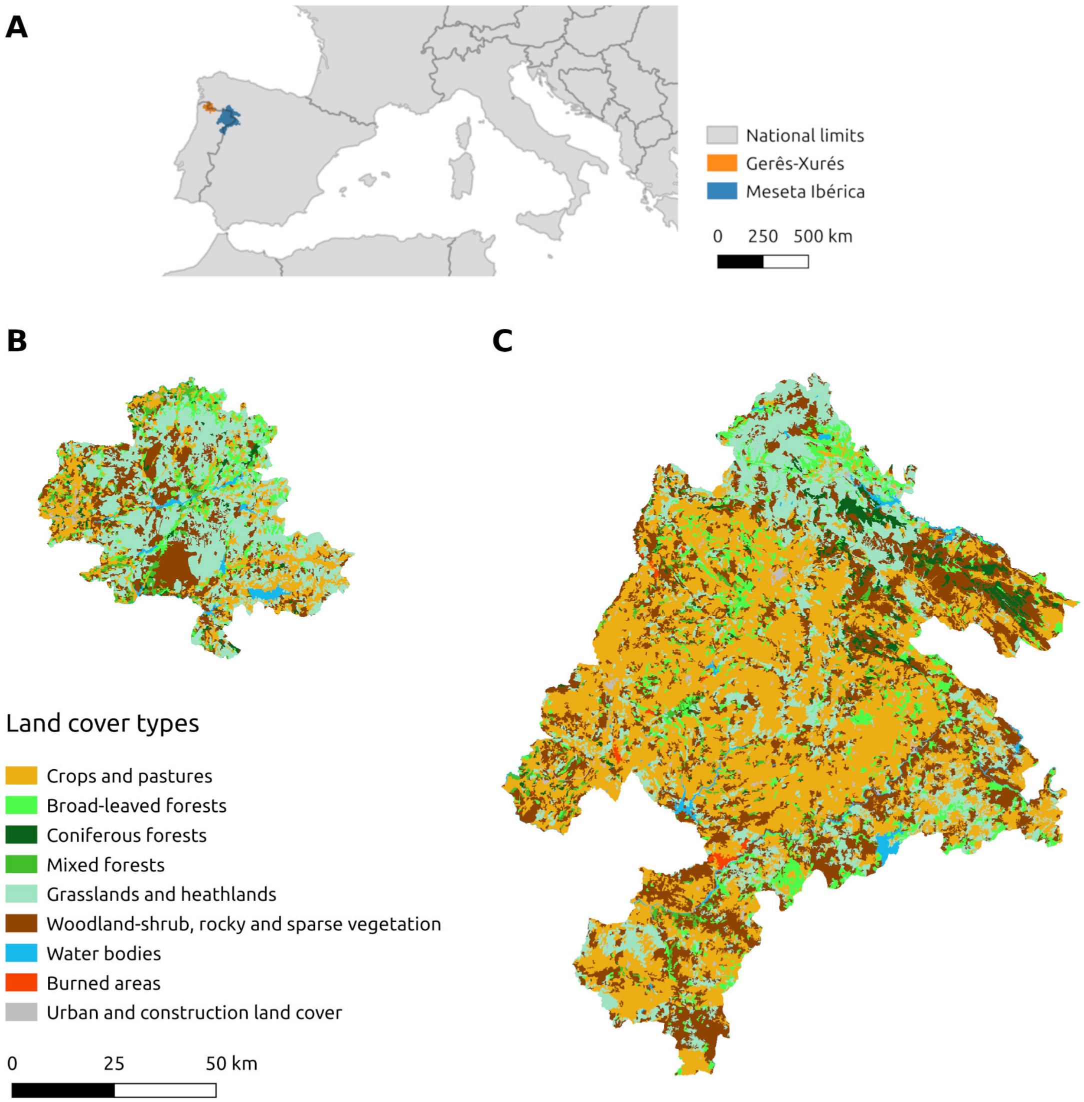
trend in the last decades (Lasanta et al. 2017). This has led to shrub and tree encroachment, increased fuel load and landscape homogenization, as well as increasing wildfire risk and intensity (Moreira et al. 2011). In rural areas of the Iberian Peninsula, fire is also used as a land management tool (e.g., clearing land for pastures; Chas-Amil et al. 2015, Tedim et al. 2016), which helps to create landscape heterogeneity but can also result in many low-intensity and small-sized fires (Chas-Amil et al. 2010). In some cases, these fires can overtake fire suppression under extreme fire-weather conditions and thus become large fires. At the same time, society perceives fire as a damaging hazard with only negative impacts (Doerr and Santín 2016) such that fire exclusion and suppression policies have been instated. In the last decades, as a result of both agricultural abandonment and a fire exclusion policy, Mediterranean landscapes have become more flammable (Moreira et al. 2011) and therefore more susceptible and vulnerable to wildfires (Lecina-Diaz et al. 2021). This close relationship between society and fire demands more holistic landscape management approaches integrating the ecological and societal domains.

The interactions between fire and landscape dynamics in these complex social-ecological systems complicate effective landscape-level fuel treatment planning and implementation (Oliveira et al. 2016, Thompson et al. 2017, Alcasena et al. 2018). Fire hazard mitigation is even more challenging in protected areas because legislation regulates and limits management, which, in concert with land-tenure constraints, complicate fuel treatment and land-use allocation (Alcasena et al. 2018). Fuel treatment strategies must consider multiple objectives and should involve the needs and views of stakeholders in relation to fire and landscape management. In the Iberian Peninsula, fuel treatments have been directed toward promotion of agro-pastoral activities, total or partial fuel removal in strategic areas (fuel breaks), and prescribed burning. However, because their implementation requires financial and human resources and machinery, the investment in this type of management tends to be limited and more focused on fire suppression. The public is oblivious to prescribed burning (Mierauskas and Pereira 2013, Ryan et al. 2013), but rural people still use fire, namely in the form of pastoral burning in the Iberian Peninsula mountains (Chas-Amil et al. 2015, Tedim et al. 2016), suggesting that a broader and more technical use of fire would be well received. Recently, fire-smart management has been defined as an integrated approach primarily based on fuel treatments through which the socio-economic impacts of fire are minimized while its ecological benefits are maximized (Hirsch et al. 2001). Fire-smart management has been proposed as an alternative to fire suppression, including fire as a social-ecological process while balancing the benefits and drawbacks of fire to human well-being (Fernandes 2013). Decreasing fire severity through fuel treatments and forest-type conversion are among the management practices known to promote more resistant and resilient landscapes under future climate change (Fernandes 2013). The effectiveness of these fire-smart strategies in terms of wildfire prevention, ecosystem services supply, and biodiversity conservation has started to be evaluated recently (Campos et al. 2020, Pais et al. 2020). However, how stakeholders perceive these types of strategies still needs to be fully understood to ensure long-term support and effective implementation (Reed 2008). In this sense, perceptions of fire and fuel management may differ across sectors and specific stakeholder interests, which can lead to societal conflicts. In general, prescribed burning can be perceived more favorably by the forestry sector, land managers, and non-governmental organizations than by citizens and private businesses (Bayne et al. 2019, Hamilton and Salerno 2020). Policymakers can also be unwilling to accept prescribed burning because they perceive rejection by the public (Varela et al. 2014). Similarly, forestry and conservation agencies often favor mechanical treatments, whereas this is unacceptable for environmentalists (McCaffrey et al. 2008, Depietri and Orenstein 2020).

Fuel management influences ecosystem services (hereafter ES) referring to the direct and indirect contributions of ecosystems to human well-being (MEA 2005). However, ES are valued differently depending on the stakeholder group because not all stakeholders benefit equally from these services. Integrating scientific knowledge on forest management with stakeholder demands on ES can improve decision planning effectiveness (Palacios-Agundez 2014). Environmental managers and researchers often perceive regulating ES as of primary importance in determining conservation strategies in protected areas (e.g., air quality, climate regulation, water regulation, and erosion control), whereas direct local users of ES have a greater interest in provisioning services, e.g., recreational fishing and clean energy provision (García-Llorente et al. 2018). In the case of fuel management, most research has focused on analyzing the environmental effects of fire on ES without considering how the perceptions of ES are affected (Vukomanovic and Steelman 2019, Roces-Díaz et al. 2021). Recent studies, which have analyzed stakeholder perceptions on fire, neglect their interdependence with other critical sectors that affect fire regime and ecosystem health (Doerr and Santín 2016, do Rosário et al. 2019). Hence, further research is needed to incorporate stakeholder needs and preferences regarding the ES benefits and drawbacks of fuel management.

In this new era of large and high-intensity wildfires, landscape management should therefore integrate social and ecological perspectives (e.g., minimizing the impact on ES) to tackle the growing wildfire problem. Possibly, the most effective way to integrate both dimensions is mainstreaming fire and its management into nature-based solutions (hereafter NbS). Nature-based solutions have been defined as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al. 2016:2). Nature-based solutions have been globally used in science, policy, practice, and private sectors to solve societal challenges, and often involve actions across broad landscapes and jurisdictional boundaries (Keesstra et al. 2018, Chausson et al. 2020, Seddon et al. 2020). Nature-based solutions have been endorsed in the IPBES global assessment report (Díaz et al. 2019), the "Horizon 2020" program (European Commission 2015), the United Nations Framework Convention on Climate Change (UNFCCC; https://unfccc.int/), and the World Economic Forum (WEF 2020). More recently, a global standard for NbS was created to increase the concept's clarity and precision and has been already successfully deployed (Chausson et al. 2020, IUCN 2020, Seddon et al. 2020). Addressing fuel management through NbS can have many advantages. Nature-based solutions is a simple concept that can be easily understood by many different societal actors, thus

Fig. 1. (A) Location of the two transboundary biosphere reserves (Gerês-Xurés in orange and Meseta Ibérica in blue) in Europe, and representation of major land-cover categories (Corine Land Cover 2018) in (B) the Gerês-Xurés and (C) the Meseta Ibérica.



helping to bring together diverse stakeholders to find effective and equitable solutions (Cohen-Shacham et al. 2019). Nature-based solutions can also be cost-effective in the long-term while ensuring ES provision and biodiversity maintenance (Cohen-Shacham et al. 2019). In this sense, it is still unknown whether the existing fuel-management approaches can be integrated under the NbS umbrella and to what extent these standard criteria can be easily accommodated.

Within this context, we look at case studies of two representative southern European mountain protected areas that are suffering from increased fire impacts and undergoing land abandonment: the Gerês-Xurés and Meseta Ibérica Transboundary Biosphere Reserves (Portugal and Spain). As in other mountain areas of the northwestern Iberian Peninsula, the abandonment of traditional and livestock activities is a common trend (Morán-Ordóñez et al. 2013) that increases fire risk. These protected areas are two social-ecological systems in which nature and society interact (e.g., the use of fire by the remaining rural communities). In addition, these biosphere reserves are located in two countries (Portugal and Spain), which increases management complexity in terms of transboundary coordination and diversity of target stakeholders (de Castro-Pardo et al. 2019). Ongoing management initiatives exist in these areas, such as rewilding in the Meseta Ibérica. Previous studies analyzed the effectiveness of fire-smart strategies for wildfire prevention, ES supply, and biodiversity conservation, showing that fire-smart and business-as-usual provided the highest carbon sequestration, whereas agriculture was the best scenario for fire suppression and conservation. Rewilding, modulated by fire suppression, may also be considered a NbS solution when agricultural policies fail (Campos et al. 2020, Pais et al. 2020). However, perceptions by stakeholders in these areas are still unknown. Therefore, the main goal of this study is to analyze stakeholder perceptions of the wildfire problem in the

Table 1. Characteristics of the study areas (location, surface, number of inhabitants, elevational range, area in Portugal and in Spain, and protected areas inside the study areas).

Biosphere Reserve	Location	Surface (km²)	Inhabitants (number of people)	Elevational range (m.a.s.l.)	Area in Portugal (%)	Area in Spain (%)	Protected areas inside the reserve
Gerês- Xurés	41º 35′ 18″ to 42º 10′ 26″ N -7º 35′ 4″ to -8º 31′ 54″ W	2679	76,301	15-1545	71%	29%	3 EU Natura 2000 sites 2 nationally designated protected areas (Peneda-Gerês National Park; Baixa Limia-Serra do Xurés Natural Park)
Meseta Ibérica	40º 40′ 32″ to 42º 15′20″ N -5º 48′ 52″ to -7º 25′ 52″ W	11,326	169,745	82-2022	58%	42%	23 EU Natura 2000 sites 4 natural parks (Montesinho, Parque Natural Lago de Sanabria y Sierras de Segundera y Porto, Douro International, and Arribes del Duero) Natural Reserve Lagunas de Villafáfila Regional Natural Park Vale do Tua Protected Landscape Albufeira do Azibo

Gerês-Xurés and Meseta Ibérica Transboundary Biosphere Reserves. Specifically, we aim to: (1) evaluate stakeholder perceptions about the impact of fire and its changes in the landscape; (2) assess their views on fuel management, including negative and positive impacts of fuel management on ES; and (3) analyze differences in stakeholder perceptions among sectors and study areas. Finally, we discuss to what extent fuel management strategies can be considered NbS based on the criteria of the IUCN global standard. To do so, we selected and surveyed relevant stakeholders in several groups in the study areas based on a structured questionnaire.

METHODS

Study area

The study area encompasses two transboundary biosphere reserves in Portugal and Spain, Gerês-Xurés and Meseta Ibérica (Fig. 1). Biosphere reserves are sites that provide local solutions to global challenges through understanding and managing changes and interactions between social and ecological systems. They involve local communities and stakeholders in planning and management (https://en.unesco.org/biosphere/about). In these two biosphere reserves, nature and society have co-evolved over millennia by means of agriculture, forestry, grazing, hunting and fishing, and other low- to moderate-intensity activities that involve local stakeholders and allow, however, the maintenance of notable biodiversity. Wildfires are common in the areas and normally dealt with by fire suppression.

Gerês-Xurés

The Gerês-Xurés Transboundary Biosphere Reserve (Fig. 1B, Table 1) was established in 2009 and is located at the transition between the Mediterranean and Eurosiberian biogeographic zones, mainly with an Atlantic climate (monthly average temperature below 22 °C; Kottek et al. 2006). The landscape is dominated by heathlands, as well as fragmented forests of deciduous trees (mostly *Quercus robur* and *Q. pyrenaica*) and conifers (mainly *Pinus pinaster*; Fig. 1B). Rural abandonment, a common trend in the area during the last century (current population density of 29.4 inhabitants km²), resulted in forest increase (Regos et al. 2015). Frequent human-caused wildfires such as unintentional agricultural burning escapes or deliberate pastoral fires are common in the study area (Chas-Amil et al. 2010, 2015, Calviño-Cancela et al. 2016), resulting in many fires and burned areas, i.e., 12,755 fires between 1983 and 2010, burning a total of 195,000 ha (Regos et al. 2015).

Meseta Ibérica

The Meseta Ibérica Transboundary Biosphere Reserve (Fig. 1C, Table 1) was established in 2015 and has a predominantly Mediterranean continental climate. The landscape is characterized by crops and pastures, heathlands, and forest. Native woodlands (*Quercus pyrenaica*, *Q. suber*, and *Q. rotundifolia*) and pine plantations (*Pinus pinaster*) dominate the latter (Fig. 1C). Depopulation is also a common trend in this area (current population density of 14 inhabitants/km²; Azevedo 2012, Sil et al. 2017). Between 2003 and 2019, the number of fires with a surface greater than 20 ha averaged 359 fires per year, while the annual burned area averaged 8912.7 ha per year (Andela et al. 2019).

Questionnaire design and stakeholder selection

An online questionnaire was conducted comprising four sections: (1) fire related questions; (2) landscape related questions; (3) landscape and fuel-management related questions; and (4) personal data (Appendix 1, Fig. A1). In the first section, the questions targeted the stakeholder perception of fire, how fire regime has changed in the study areas in the last 30 years, and how it is expected to change in the next 30-40 years. We also asked about perceptions on the main causes of large fires and preferred policies to prevent them. The second section was aimed at understanding how stakeholders perceived past and envisaged future changes in the landscape, as well as how landscape should change to avoid large fires. In the third section, respondents were asked to rank current firefighters' fire-suppression capacity under different combined situations and landscape configurations (e.g., shrubland, medium-sized fires) using a four-point Likert-scale ranging from "inadequate" to "very good." Respondents were also requested to rank specific alternative management strategies to prevent large fires using a six-point Likert-scale ranging from "absolutely unnecessary" to "absolutely necessary." In addition, we asked about the perceived societal benefits of these management strategies about four targets: (1) reduction of large forest fires; (2) maintenance of ES; (3) biodiversity conservation; and (4) local economic development. We also asked about potential benefits of these management strategies on ES, using

Table 2. Description (definition, examples, and relevance in fire management) of the stakeholders' sectors in the study areas.

Stakeholder group	Definition	Examples	Relevance in fire management in the study areas
Forest actors and civil protection	Associations, institutions, and agencies whose main activities are directly related to the forestry sector	Forest owners and forest management associations, fire prevention and suppression organizations (e.g., fire-fighters), civil protection agencies	High/Very high Involved directly in the implementation of prevention and suppression measures
Government	Government at the town, municipal and district levels, as well as other public institutions, excluding the ones directly related to the forest sector	Municipalities, regional or sectoral institutions	Very high Responsible for fire management plans design and implementation at different administrative levels and also for reporting and, in some cases, firefighting
Local development	Stakeholders directly involved in the use of the territory. Given that forest-fire management is the basis of this study, forest actors and civil protection are considered apart (first sector)	Linked to agriculture and livestock, hunting, tourism, leisure and environmental education activities	Medium/Low Only occasionally involved, although their role in fire hazard reduction at the landscape level is high (see Appendix 1, Table A1)
Nature conservation	Associations or institutions whose objectives are related to biodiversity and nature conservation	Nature conservation organizations, environmental associations (e.g., NGOs), protected areas headquarters	Medium/Low (same as above)
Research	Universities and research institutions with scientific background of the study areas	Universities and research centers in Galicia and northern Portugal that have conducted previous studies in the biosphere reserves	Low Researchers contribute to formal education in fire-related fields (e.g., forestry) and occasionally (in)formal training of fire management personnel. In Portugal, the new Fire Management Agency is an associate of the ForestWISE collaborative laboratory (responsible for research, innovation, and transfer of technology activities).

two different ES for each ES' group: provisioning (timber and wood, agriculture and livestock); regulating (climate regulation, hydrological control); and cultural (cultural identity, tourism and recreation). We also questioned stakeholders on the effectiveness of fire-prevention policies and about the transboundary coordination and cooperation between landscape management and prevention, and between fuel management and suppression. Finally, in section four, we asked about additional personal information: organization, age, sector, relevance in the decision-making process, years of experience in the sector, study area, and nationality (Appendix 1, Fig. A1). Some questions were mandatory or/and multiple choice, and respondents also had the option of answering anonymously. A complete description of the fuel-management approaches considered is given in Appendix 1, Table A1.

We identified the relevant sectors based on existing literature and co-authors' knowledge of the areas: forest actors and civil protection, government, local development, nature conservation, and research (see detailed description in Table 2). Once the main sectors were defined, we identified potential specific stakeholders through co-authors' knowledge of the study areas, internet information (e.g., webpages, social networks), and snowball sampling (i.e., asking key informants to name other relevant contacts). Then, we sent the questionnaire through a personalized email to each stakeholder and study area (Gerês-Xurés or Meseta Ibérica) in the native tongue of each stakeholder (i.e., Spanish or Portuguese). The questionnaire was launched in January 2021 and remained open to the respondents until May 2021. In total, 347 questionnaires were sent out to different stakeholders using Google Forms (docs.google.com/forms) and the Convertkit platform (convertkit.com), and 114 answers were received. There are constraints in online questionnaires, such as not all individual stakeholders have access to the platform and local citizens may therefore not be included. However, the representativeness of each stakeholder group is shown in the questionnaire metrics section.

Data analysis

To evaluate the stakeholder perceptions, we calculated the percentage of different responses for each question. Then, we plotted them using a standard bar or Likert scale plot per question through the ggplot and the likert R-packages (Bryer and Speerschneider 2016, R Core Team 2020). In the case of ES trade-offs, we calculated the ratio between the percentage of responses perceiving positive and negative impacts of each management strategy, i.e., a ratio of 1 means the same percentage between positive and negative impacts, > 1 means more positive than negative impacts, and < 1 means more negative than positive impacts. To analyze the statistical differences among sectors and study areas on all the answers, we applied Pearson's Chi-squared tests and Bonferroni posthoc tests using the stats, corrplot, and chisq.posthoc.test R-packages (Wei and Simko 2017, Ebbert 2019, R Core Team 2020). The study areas considered were: (1) Gerês-Xurés; and (2) Meseta Ibérica, which are directly associated with the study areas; and (3) whole region, not directly associated with the two study areas but influential in the whole region (e.g., North of Portugal, provincial level).

Global standard on nature-based solutions (NbS)

Based on stakeholder support, we have discussed to what extent fuel management strategies can be considered NbS, following the IUCN global standard on NbS. This standard has eight criteria (IUCN 2020):

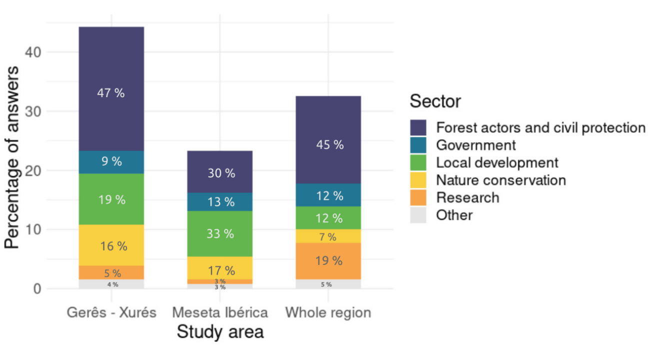
- Criterion 1. NbS effectively address societal challenges.
- Criterion 2. Design of NbS is informed by scale.
- Criterion 3. NbS result in a net gain to biodiversity and ecosystem integrity.
- Criterion 4. NbS are economically viable.
- Criterion 5. NbS are based on inclusive, transparent, and empowering governance processes.
- Criterion 6. NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits.
- Criterion 7. NbS are managed adaptively, based on evidence.
- Criterion 8. NbS are sustainable and mainstreamed within an appropriate jurisdictional context.

RESULTS

Questionnaire metrics

In total, 114 responses were received, representing 33% of the overall number of questionnaires sent. Most of the answers were from Gerês-Xurés (44%), followed by respondents from the whole region (33%), and respondents from Meseta Ibérica (23%). Forestry actors and civil protection had the highest response rate (30-47%), followed by local developers (12-33%; Fig. 2; Appendix 1, Table A2). Gender and age data were incomplete. We could only know the gender of 55% of the respondents because the rest answered representing an institution or anonymously. The known data revealed a highly unbalanced gender and age sample. Only 21% of respondents were female and 75% were 40-49 years old (18% 20-39 years old, and 7% older than 60 years). Sixty-eight percent of respondents had average to very high relevance in decision making, and 46% had 15-30 years of experience in the sector (30% had 10-15 years of experience, and 6% more than 30 years of experience). Nationality was relatively balanced (41% Spanish and 59% Portuguese).

Fig. 2. Percentage of answers from the study areas, i.e., Gerês-Xurés, Meseta Ibérica, and whole region (referring to respondents not directly related with the two study areas but influential in the region) and sectors (forest actors and civil protection, government, local development, nature conservation, research, and other).



Stakeholder perceptions

Fire and its changes in the landscape

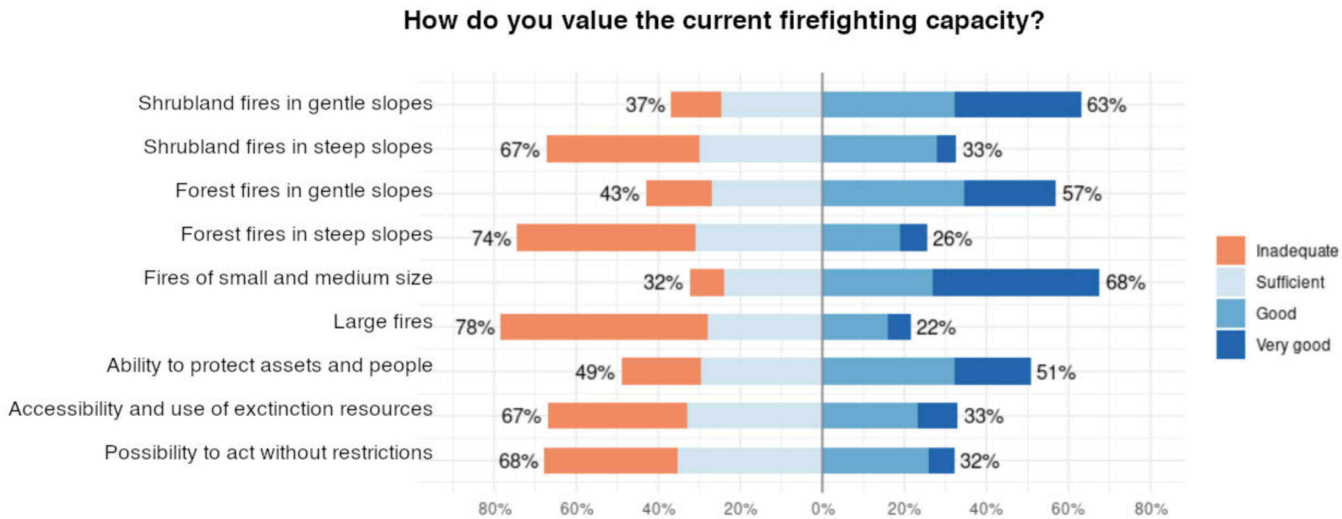
Overall, most stakeholders considered that fire must be managed (77%), supporting fire prevention rather than suppression policies. However, nearly half (49%) considered that it has catastrophic effects on the landscape and human lives. Still, only 5% considered that fire must be suppressed under any circumstance (see Appendix 1, Table A3). Regarding past and future changes in fire regimes, they perceived more high-intensity fires impacting the study regions than in the last 30 years (46%). They also expected that this situation would continue in the future in the absence of management (52%; Appendix 1, Table A3). An overwhelming majority (92%) of stakeholders perceived rural abandonment as one of the main causes of large wildfires (Appendix 1, Table A4). They also thought that the absence of an integrated fire management policy is an important cause of large wildfires (57%), followed by inefficient fire prevention systems and/or with lack of resources (53%), and climate change (47%). Accordingly, they thought that large wildfires could be prevented with integrated fire management policies (73%), increasing fire prevention resources (69%), and enhancing the resilience and resistance of forests through landscape management (68%) (Appendix 1, Table A3).

Fuel management

Current fire-fighting capacity is considered good or very good when conditions are "not complex" (i.e., shrubland and forest in gentle slopes, small to moderately sized fires), being, however, inadequate in "more complex" situations (i.e., steep slopes), especially in large fires (Fig. 3). In addition, stakeholders accepted all the fuel management strategies suggested, except chemical treatments, perceiving more positive than negative effects of fuel management on forest ES (Fig. 4). In particular, promoting agriculture and livestock is the most supported management strategy (97%), with more benefits for local economic development (Fig. 5). Prescribed burning is perceived as the best strategy for reducing large fires (Fig. 5), yet almost one quarter of the respondents (22 %) stated that it is not necessary (Fig. 4). The strategies that were thought to equally benefit the four targets (i.e., reduction of large fires, ES maintenance, biodiversity conservation, and economic development) were agriculture and livestock promotion and introduction of large herbivores (Fig. 5). The highest stakeholder support for biodiversity conservation was in introducing large herbivores and changing forest composition (e.g., by replacing fast-growing conifer plantations less resistant to fire with broadleaved species) to increase fire resistance (Fig. 5). Promoting agriculture and livestock and introducing large herbivores received the highest support from stakeholders as economically viable fuel management strategies to reduce large fires (Fig. 5)

In general, stakeholders perceived more positive impacts (mean ± standard error: 89.5 ± 4.8%) than negative impacts (70.8 ± 3.4%) of fuel management on ES. The highest positive impacts are in provisioning services: timber and wood (23.5 ± 4.8%), followed by agriculture and livestock (22.8 ± 3.8%). Promoting agriculture and livestock and introducing large herbivores are the management activities related to the provision of more cultural services (23-25% of stakeholders perceived an impact on cultural identity, and 15-25% on tourism and recreation). Chemical

Fig. 3. Likert-scale plots of the stakeholders' responses regarding the current firefighting capacity in different situations. The levels of valuation are inadequate, sufficient, good, and very good.



treatments were perceived by stakeholders to result in negative (88%) rather than positive (58%) effects on ES (i.e., for all ES considered except timber and wood; Fig. 6). Transboundary coordination is rated as quite inadequate or nonexistent (62-67%), and only 14-22% rated it as adequate or very good (Appendix 1, Table A5).

Differences among stakeholder sectors and study areas
Overall, we did not find significant differences among stakeholder sectors and biosphere reserves. Significant differences among stakeholder sectors were observed only in particular cases, which suggests a general agreement on how fire, fuel management, and its landscape impacts are perceived. Specifically, the frequency of people perceiving that there will be fewer high-intensity/severity fires in the future is significantly higher within the forest actors and civil protection sector than in the rest of the sectors (Appendix 1, Tables A6, A7). The local development sector valued more positively firefighting capacity (in terms of accessibility and use of fire suppression resources) in small and medium-sized fires than other sectors (p-value < 0.01; Appendix 1, Tables A8, A9). In contrast, the nature conservation sector perceived inadequate firefighting capacity in shrubland fires on gentle slopes and in small to medium-sized fires (Appendix 1, Tables A8, A9). Concerning the study areas, the frequency of stakeholders perceiving that high-intensity fires are now more common than in the last 30 years and that this trend will continue in the future is significantly higher in Gerês-Xurés than in Meseta Ibérica (Appendix 1, Tables A6, A7). Finally, transboundary coordination effectiveness is better valued in Meseta Ibérica than in Gerês-Xurés (Appendix 1, Tables A10, A11).

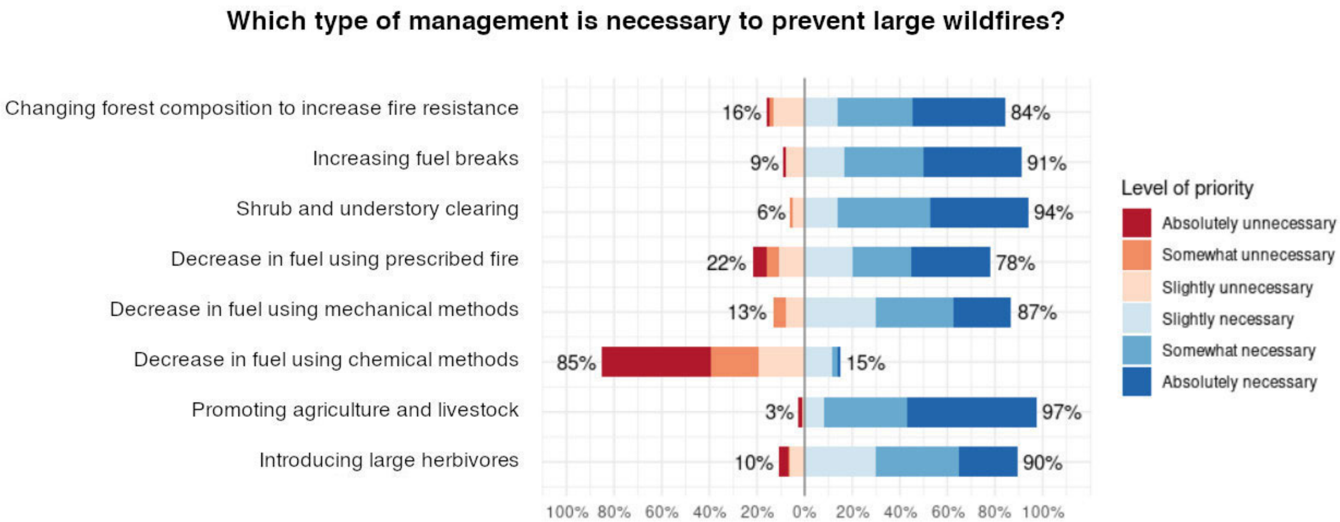
DISCUSSION

Stakeholder perceptions

Fire and its changes in the landscape
Although fires are an ecological driver in Mediterranean forests, and species have developed different strategies to trigger, resist, and recover from fires (Keeley and Fotheringham 2000), the perception that fires are catastrophic still prevails (Appendix 1, Table A3). Fire is seldom viewed positively by society, given its impacts on peoples' properties and lives (Doerr and Santín 2016, but see also Pereira et al. 2016 in which fire severity is low to moderate). However, media reporting is very often uninformed and biased, overstating the negative impacts of fire, focusing on the firefighting response, and lacking fire ecology concepts, e.g., Smit et al. (2022). The perception of more high-intensity fires in the study regions than in the last 30 years is supported by the literature in the case of increased burned area in northwest Portugal (Silva et al. 2019). Although previous studies showed a strong belief that arsonists are causing wildfire ignitions (Calviño-Cancela and Cañizo-Novelle 2018, Palaiologou et al. 2021), this is not the case in our study area (Appendix 1, Table A4). Rural abandonment is a major social-ecological issue in the mountain areas of southern Europe, where agriculture abandonment drives shrubland encroachment and conversion to forests (Moreira et al. 2011, Ameztegui et al. 2021). The low support for fire suppression policies (Appendix 1, Table A3) suggests a paradigm change from the idea that fire must always be suppressed (Snider et al. 2006, Mateus and Fernandes 2014). In fact, suppression alone as a strategy to avoid large wildfires has been proven to be costly and ineffective (Williams et al. 2011, Wunder et al. 2021), potentially feeding back into increased landscape flammability (Fernandes et al. 2020, Moreira et al. 2020). Indeed, stakeholders prioritized wildfire prevention through integrated fuel management policies, which has been previously suggested as the main challenge to decrease fire impacts and the vulnerability of social-ecological systems (Tedim et al. 2013, Mateus and Fernandes 2014).

Fuel management
Stakeholders perceived benefits of all fuel management alternatives to reduce large wildfires, except chemical treatments (Fig. 4) mainly because, in contrast to other regions, the social acceptability of using herbicides to control understory vegetation is low in Europe (except for *Eucalyptus* plantations in Portugal; Mirra et al. 2017). Other methods, such as mechanical treatments,

Fig. 4. Likert-scale plots of the stakeholders' responses regarding perceptions on fuel-related fire management strategies to prevent large wildfires depicting different levels of priority: absolutely unnecessary, somewhat unnecessary, slightly unnecessary, slightly necessary, somewhat necessary, and absolutely necessary.



are much more common and receive economic incentives (Ammer et al. 2011, McCarthy et al. 2011). Considering that rural abandonment was the most claimed driver of wildfires in the two study areas, it seems reasonable that stakeholders also strongly support agriculture and livestock promotion (Fig. 4). Hence, methods such as mechanical thinning are preferred (Toman et al. 2014, Pereira et al. 2016), even if their hazard-reduction effectiveness is lower (Wimberly et al. 2009).

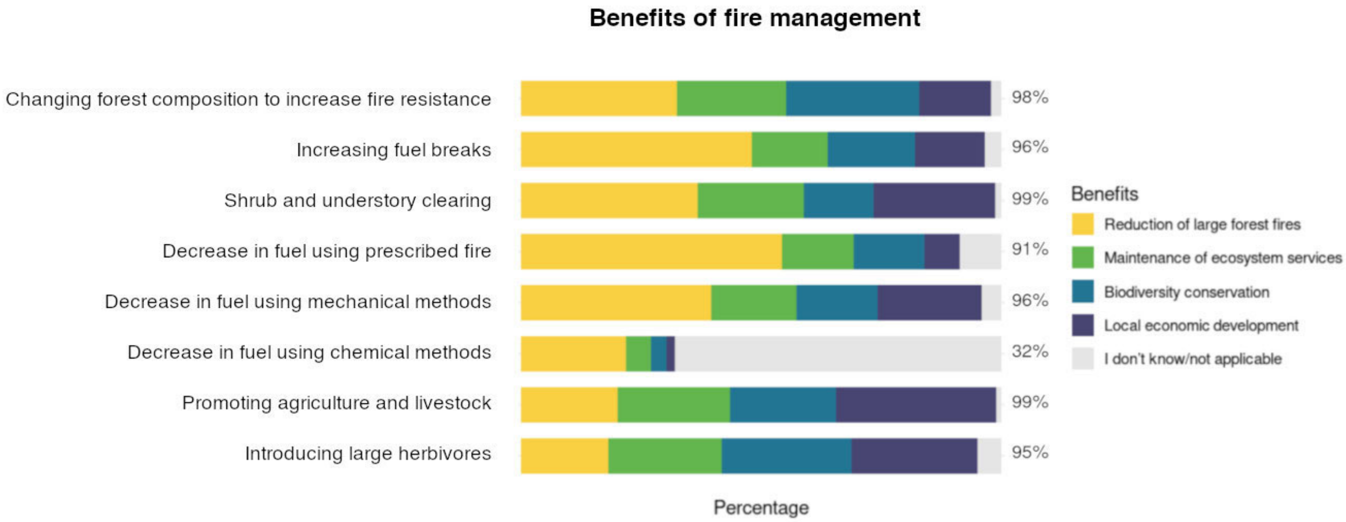
The highest positive impacts of fire management are perceived in provisioning services (wood and timber, agriculture and livestock; cf. Fig. 6), probably because most of the stakeholders benefit from these services (e.g., the forestry sector benefits from wood). Although prescribed fire was not widely accepted, reducing biomass through burning is perceived as beneficial for agriculture and livestock, mainly because fire has been historically used to clear land for agriculture purposes (Regos et al. 2015). Interestingly, management strategies that have fewer negative visual impacts (i.e., promoting agriculture and livestock and introducing large herbivores) are the management activities perceived to provide more cultural services (Fig. 6). Less aesthetic management, such as fuel breaks and thinning, was previously perceived as negative for cultural ES (Depietri and Orenstein 2020).

Given that international boundaries rarely coincide with ecological regions, protected areas often need to be expanded beyond their national boundaries to create coherent landscape and management entities (Wolmer 2003, Wiens and Bachelet 2010). Transboundary coordination is not only desirable from a management effectiveness point of view, but also for efficiency because greater benefits can be achieved at lower costs (Kark et al. 2009); this includes transboundary coordination at the landscape level for fire prevention and suppression. In our study areas, transboundary collaboration/coordination is rated as quite inadequate or even nonexistent (Appendix 1, Table A5) because the only instruments to enable this coordination are the biosphere reserve and a jurisdictional instrument for Gerês-Xurés and Meseta Ibérica, respectively (https://www.reservabiosferageresxures.eu/en/project-presentation; https://www.biosfera-mesetaiberica.com/es), and these were established very recently. However, previous studies point out that assessing the costs and benefits of management and including the stakeholders at all levels would ensure greater conservation objectives, even in the absence of international cooperative management (Busch 2008, Wiens and Bachelet 2010, de Castro-Pardo et al. 2019).

Differences among stakeholder sectors and study areas

There was consensus among different groups of stakeholders and study areas about the perception about fire, its changes in the landscape, and fuel management strategies' effectiveness (Appendix 1, Tables A6, A8, and A10). The absence of discrepancies among stakeholders can facilitate planning and implementation of the fuel management strategies that received the most support (i.e., promoting agriculture and livestock, shrub and understory clearing). Therefore, management decisions can be better adapted to the socio-cultural and environmental conditions of the areas, which would enhance their quality and effectiveness (Reed 2008). Under these circumstances, a common framing for wildfire management, including improving performance measurement, supporting greater integration of fire and land management planning, as well as increasing transparency and collaboration, would be possible to effectively address fire management (Schultz et al. 2019). The transboundary coordination was better valued in the Meseta Ibérica mainly because in this study area, a jurisdictional instrument of territorial cooperation was specifically created to facilitate and promote territorial cooperation among its members, as well as its economic and social cohesion (https://www.biosfera-mesetaiberica.com).

Fig. 5. Percentage of benefits of the different fire management strategies perceived by the stakeholders in terms of reduction of large wildfires, maintenance of ecosystem services, biodiversity conservation, and local economic development. Percentage values indicate the total benefits for each management strategy (i.e., without including the category "I don't know/not applicable").



Reflections on stakeholder perceptions using the nature-based solutions (NbS) criteria

Nature-based solutions have been suggested as mechanisms for transformative change toward more resilient and sustainable landscapes for people and nature. The results of the stakeholder questionnaire allowed us to discuss to what extent fuel management strategies can be accommodated in the frame of NbS according to the IUCN global standards (IUCN 2020). In particular, promoting agricultural and livestock uses, modifying forest species composition to increase fire resistance, and introducing large herbivores have the potential to become effective NbS in the regions. In fact, agroforestry in southern Portugal has been previously considered a NbS to improve traditional and sustainable land use for semi-arid regions, and rewilding of agricultural catchments in Slovenia has been also considered a NbS with soil and landscape benefits (Keesstra et al. 2018). Mainstreaming these fuel management strategies into IUCN standards of NbS should facilitate their implementation as sustainable and economically viable solutions to the increasing wildfire hazard in the mountain abandoned landscapes of southern Europe.

Six of the eight criteria can be easily incorporated.

Criterion 1: NbS effectively address societal challenges

The societal challenges identified by stakeholders are the increase in wildfire intensity and severity (exacerbated by insufficient firefighting capacity in large fires, and inadequate transboundary collaboration/coordination; Appendix 1, Tables A3-A5) and rural abandonment, which compromises food security. These challenges can be addressed by fire management by promoting agriculture and livestock, modifying forest species composition to increase fire resistance, and introducing large herbivores because these strategies are receiving the greatest support from stakeholders.

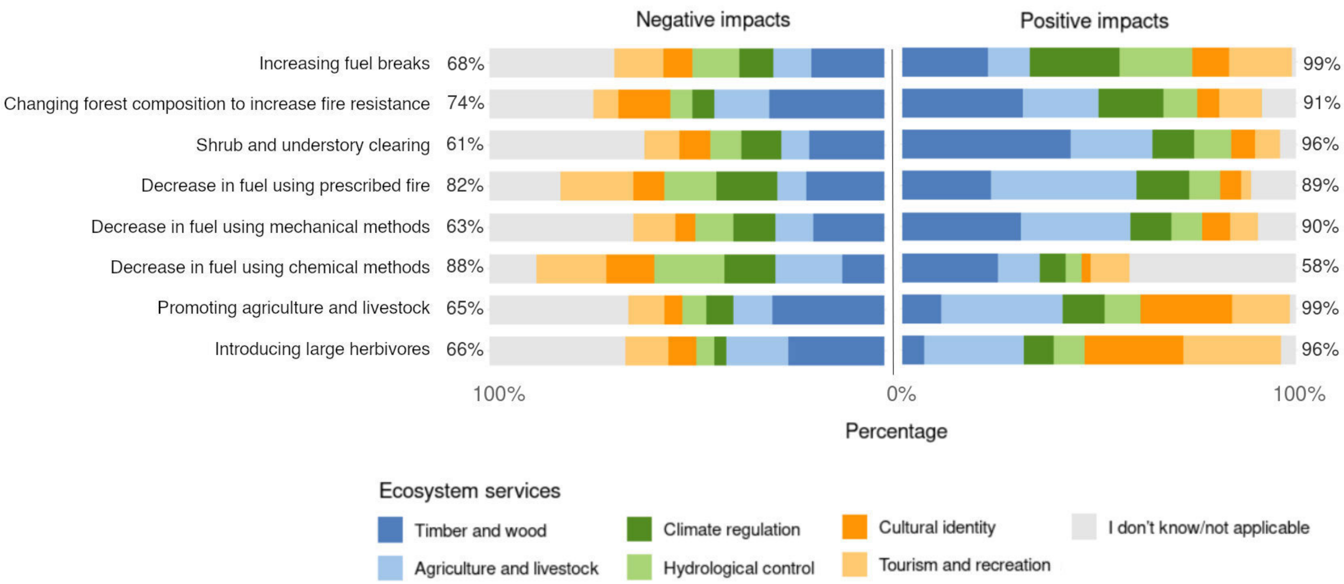
Criterion 2: design of NbS is informed by scale (recognizing the complexity and uncertainty that occur in living dynamic landscapes)

The different fuel management strategies can be implemented in the two transboundary protected areas (Gerês-Xurés and Meseta Ibérica), in which the economic, ecological, and societal aspects are considered. Regarding local economic development, the stakeholder questionnaire showed that promoting agriculture and livestock was the fuel management strategy expected to have more benefits (Fig. 6). The strategies that were thought to equally benefit the four targets (i.e., reduction of large fires, ES maintenance, biodiversity conservation, and economic development) were agriculture and livestock promotion and the introduction of large herbivores (Fig. 6). The EU's common agricultural policy (CAP) is a partnership between agriculture and society that supports farmers and ensures Europe's food security. Among its objectives, the CAP aims to keep the economy alive in rural areas by promoting jobs in farming, agri-food industries, and associated sectors. In this sense, the ongoing reform of the CAP, adopted in 2021 (European Commission 2022), offers an opportunity to promote these strategies over the next few years and solve a critical issue in remote mountainous areas strongly affected by rural abandonment. Considering member states' specific needs, national-level CAP strategic plans will combine a wide range of local and EU-level objectives that can foster agriculture and livestock activities as NbS to wildfires in our study areas.

Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity

The highest support for biodiversity conservation was in introducing large herbivores and changing forest composition to increase fire resistance (Fig. 5). This is in line with on-going initiatives of rewilding in Meseta Ibérica (https://rewilding-portugal.com). However, previous studies in the Gerês-Xurés Biosphere Reserve showed that the expansion of (high nature value) farmlands has the highest outcomes for biodiversity

Fig. 6. Bar plots showing stakeholders' perceptions of the negative (left panel) and positive (right panel) impacts of fire management strategies on ecosystem services (in relative percentages). Color bars represent different classes of ecosystem services: provisioning services in blue (timber and wood, agriculture and livestock), regulating services in green (climate regulation, hydrological control), and cultural services in orange (cultural identity and tourism and recreation). Percentage values indicate the total negative and positive impacts on ecosystem services for each management strategy (category "I don't know/not applicable" not included).



conservation in number of species, whereas rewilding initiatives were more beneficial for species of conservation concern (Campos et al. 2020, Pais et al. 2020). In addition, land-use management policies aiming at promoting traditional agricultural activities could reduce the potential area burned by large fires and improve the effectiveness of fire suppression in the Gerês-Xurés (Campos et al. 2020, Pais et al. 2020).

Criterion 4: NbS are economically viable

It is essential to frame fuel management strategies as NbS to ensure their economic viability and, therefore, their applicability. Promoting agriculture and livestock and introducing large herbivores received the highest support from stakeholders for the local economic development of the area (Fig. 5). The questionnaire did not account for the economic costs and benefits of implementing each strategy; therefore, cost-benefit analysis should be developed to ensure their economic viability. Nevertheless, the overall stakeholder acceptance is a firm step forward. These economic assessments should account for the effects of these fuel management strategies in wildfire damages and avoided damages to the whole landscape, that is, considering the ecosystem services that affect financial returns to landowners (Lecina-Diaz et al. 2023). In addition, these strategies can potentially generate economic savings by reducing wildfire suppression costs. These socioeconomic assessments will help to identify fuel management strategies that are more economically viable, which will greatly facilitate their successful implementation.

Criterion 5. NbS are based on inclusive, transparent, and empowering governance processes

The questionnaire showed overall agreement for the use of all fuel management strategies to prevent large wildfires (78-97%, except chemical treatments; Fig. 4). This could be a baseline for facilitating the initial step in the life cycle of the co-design, co-implementation, co-evaluation, and monitoring process of NbS being transparent and accessible to all the stakeholders. However, the inadequate transboundary coordination in the biosphere reserves (especially in Gerês-Xurés) could probably impede the governance process, thus additional mechanisms for enhancing coordination should be reinforced.

Criterion 6. NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits

All management strategies except the use of chemical methods are perceived to have more positive than negative impacts in ES (Fig. 6). Previous studies in the areas have shown that promoting agriculture would provide further fire-suppression opportunities while simultaneously ensuring biodiversity conservation within (and around) protected areas (Pais et al. 2020, Campos et al. 2022, Cánibe et al. 2022). "Fire-smart" scenarios could be the most advantageous for climate regulation services while also contributing to fire regulation (Campos et al. 2022, Cánibe et al. 2022), facilitating the transition toward more fire-resilient landscapes (Fernandes 2022, Regos 2022).

Criterion 7 (i.e., NbS are managed adaptively, based on evidence) and 8 (i.e., NbS are sustainable and mainstreamed within an appropriate jurisdictional context) cannot be directly assessed with the results of the questionnaire, but further research can incorporate them. In particular, adaptive management can be implemented in the process of design, implementation, evaluation, and monitoring of the NbS life cycle (criterion 7). This will allow changing the strategy or actions if required in any step of the feedback loop process of continuous learning (IUCN 2020). Given that local decision makers and other key stakeholders have given support to most of the fuel management strategies, this is a first, although very preliminary, step to make significant contributions to the economic, social, and conservation targets of the areas, ensuring the long-term implementation and sustainability of these management strategies (criterion 8). Nevertheless, additional studies are needed to engage the stakeholders more actively in the management of these areas, as well as to evaluate the cost-effectiveness of fuel management strategies. Indeed, in this era of megafires, this study is a baseline for the co-design and co-implementation of these fuel management strategies as NbS, which could be a first step to its successful application in solving the societal challenges and contributing to the sustainable development of the areas.

CONCLUSION

There is evidence that incorporating the stakeholder perceptions into management decisions improves its societal acceptability and effectiveness (Rauschmayer et al. 2009, Apostolopoulou et al. 2012). This study showed stakeholder perceptions about fire, its impacts on the landscape, and the fire management opportunities in two transboundary biosphere reserves in Portugal-Spain (Gerês-Xurés and Meseta Ibérica). Overall, there is general agreement among stakeholders across sectors and study areas. They state that fire must be managed and support fire prevention rather than suppression policies. They also perceive that rural abandonment is the main cause of large wildfires, with more high-intensity fires impacting the study regions than in the last 30 years, a trend expected for the future in the absence of management. Regarding fuel management, all strategies except chemical treatments were accepted by the stakeholders, who perceive more positive than negative effects of fire management on forest ES. In particular, promoting agricultural and livestock uses, modifying forest species composition to increase fire resistance, and introducing large herbivores have great potential to become effective NbS in these regions. Despite the lack of cost-benefit analysis, the overall stakeholder acceptance of these management options and their alignment with the IUCN standards of NbS is a firm step toward successful implementation. In addition, mainstreaming these fuel management strategies as NbS into the toolkit of decision makers offers environmentally and economically viable solutions to the societal challenge that large wildfires pose to mountain regions across southern Europe.

Nevertheless, additional studies are needed to engage the stakeholders more actively in the management of these areas, as well as to evaluate the cost-effectiveness of fire management strategies. Indeed, this study is a first-step analysis representing a base for future co-design and co-implementation of these fire management strategies as NbS, which can help in its successful application to solving the societal challenges and contributing to the sustainable development of the areas.

Author Contributions:

J. C. and S.P. designed the questionnaire; J. L.-D. launched the questionnaire, gathered and analyzed the data; C. C.-S., J. C. A., J. G., P. M. F., N. A., J. V. R.-D., M. A., L. B., M-L. C.-A., A. D., A. L., F. M., J. T., and J. P. H. provided input during the process; J.L-D. wrote the manuscript with all authors providing input; A. R. supervised the study.

Acknowledgments:

We kindly acknowledge all the people that voluntarily answered the questionnaire that made this study possible. This research was funded by national funds through the FCT - Foundation for Science and Technology, I. P., under the FirESmart project (PCIF/MOG/0083/2017). J. L.-D. received a postdoctoral fellowship through the FCT - Foundation for Science and Technology, I. P., under the FirESmart project (PCIF/MOG/0083/2017) and is currently supported by Alexander von Humboldt Foundation. A. R. was funded by the Xunta de Galicia (postdoctoral fellowship ED481B2016/084-0) and IACOBUS program (INTERREG V- A España - Portugal, POCTEP 2014-2020). A. R., J. V. R.-D. and N. A. are supported by "Juan de la Cierva" fellowship funded by the Spanish Ministry of Science, Innovation and Universities (IJC-2019-041033, IJCI-2019-038826-I and FJC2020-046387-I, respectively). C. C-S. is supported by the "Contrato-Programa" UIDP/04050/2020 funded by national funds through the Fundação para a Ciência e Tecnologia I. P. A.L. is supported by national funds through FCT - Fundação para a Ciência e a Tecnologia, I. P., in the context of the Transitory Norm - DL57/2016/CP1440/CT00. This study is also supported by the SHELTER project (GA 821282).

Data Availability:

The data/code that support the findings of this study are available on request from the corresponding author, J. L.-D. None of the specific data are publicly to protect information that could compromise the privacy of research participants.

LITERATURE CITED

Abatzoglou, J. T., A. P. Williams, L. Boschetti, M. Zubkova, and C. A. Kolden. 2018. Global patterns of interannual climate–fire relationships. Global Change Biology 24(11):5164–5175. https://doi.org/10.1111/gcb.14405

Alcasena, F. J., A. A. Ager, M. Salis, M. A. Day, and C. Vega-Garcia. 2018. Optimizing prescribed fire allocation for managing fire risk in central Catalonia. Science of The Total Environment 621:872–885. https://doi.org/10.1016/j.scitotenv.2017.11.297

Ameztegui, A., A. Morán-Ordóñez, A. Márquez, Á. Blázquez-Casado, M. Pla, D. Villero, M. B. García, M. P. Errea, and L. Coll. 2021. Forest expansion in mountain protected areas: trends and consequences for the landscape. Landscape and Urban Planning 216:104240. https://doi.org/10.1016/j.landurbplan.2021.104240

Ammer, C., P. Balandier, N. S. Bentsen, L. Coll, and M. Löf. 2011. Forest vegetation management under debate: an introduction. European Journal of Forest Research 130(1):1–5. https://doi.org/10.1007/s10342-010-0452-6

Andela, N., D. C. Morton, L. Giglio, and G. R. Randerson. 2019. Global fire atlas with characteristics of individual fires, 2003-2016. ORNL DAAC, Oak Ridge, Tennessee, USA.https://doi.org/10.3334/ORNLDAAC/1642

Anderegg, W. R. L., A. T. Trugman, G. Badgley, C. M. Anderson, A. Bartuska, P. Ciais, D. Cullenward, C. B. Field, J. Freeman, S. J. Goetz, J. A. Hicke, D. Huntzinger, R. B. Jackson, J. Nickerson, S. Pacala, and J. T. Randerson. 2020. Climate-driven risks to the climate mitigation potential of forests. Science 368(6497). https://doi.org/10.1126/science.aaz7005

Apostolopoulou, E., E. G. Drakou, and K. Pediaditi. 2012. Participation in the management of Greek Natura 2000 sites: evidence from a cross-level analysis. Journal of Environmental Management 113:308–318. https://doi.org/10.1016/j.jenvman.2012.09.006

Azevedo, J. C. 2012. Florestas, ambiente e sustentabilidade: uma abordagem centrada nos serviços de ecossistemas das florestas do distrito de Bragança. Academia das Ciências de Lisboa, Lisboa, Portugal. https://bibliotecadigital.ipb.pt/bitstream/10198/7135/3/Florestas_Ambiente_e_Sustentabilidade.pdf

Bayne, K. M., V. R. Clifford, B. R. Baillie, and H. G. Pearce. 2019. Fire as a land management tool: rural sector perceptions of burn-off practice in New Zealand. Rangeland Ecology and Management 72(3):523–532. https://doi.org/10.1016/j.rama.2018.12.001

Bowman, D. M. J. S., G. J. Williamson, J. T. Abatzoglou, C. A. Kolden, M. A. Cochrane, and A. M. S. Smith. 2017. Human exposure and sensitivity to globally extreme wildfire events. Nature Ecology and Evolution 1(3):0058. https://doi.org/10.1038/s41559-016-0058

Bryer, J., and K. Speerschneider. 2016. likert: analysis and visualization likert items. R Foundation for Statistical Computing, Vienna, Austria. https://cran.r-project.org/package=likert

Busch, J. 2008. Gains from configuration: the transboundary protected area as a conservation tool. Ecological Economics 67 (3):394–404. https://doi.org/10.1016/j.ecolecon.2007.12.012

Calviño-Cancela, M., and N. Cañizo-Novelle. 2018. Human dimensions of wildfires in NW Spain: causes, value of the burned vegetation and administrative measures. PeerJ 2018(9). https://doi.org/10.7717/peerj.5657

Calviño-Cancela, M., M. L. Chas-Amil, E. D. García-Martínez, and J. Touza. 2016. Wildfire risk associated with different vegetation types within and outside wildland-urban interfaces. Forest Ecology and Management 372:1–9. https://doi.org/10.1016/j.foreco.2016.04.002

Campos, J. C., J. Bernhardt, N. Aquilué, L. Brotons, J. Domínguez, Â. Lomba, B. Marcos, F. Martínez-Freiría, F. Moreira, S. Pais, J. P. Honrado, and A. Regos. 2020. Using fire to enhance rewilding when agricultural policies fail. Science of the Total Environment 755:142897. https://doi.org/10.1016/j.scitotenv.2020.142897

Campos, J. C., S. Rodrigues, Â. Sil, V. Hermoso, T. R. Freitas, J. A. Santos, P.M. Fernandes, J. C. Azevedo, J. P. Honrado, and A. Regos. 2022. Climate regulation ecosystem services and biodiversity conservation are enhanced differently by climate- and fire-smart landscape management. Environmental Research Letters 17:054014. https://doi.org/10.1088/1748-9326/ac64b5

Cánibe Iglesias, M., V. Hermoso, J. C. Campos, C. Carvalho-Santos, P. M. Fernandes, T. R. Freitas, J. P. Honrado, J. A. Santos, Â. Sil, A. Regos, and J. C. Azevedo. 2022. Climate- and fire-smart landscape scenarios call for redesigning protection regimes to achieve multiple management goals. Journal of Environmental Management 322:116045. https://doi.org/10.1016/j.jenvman.2022.116045

Chas-Amil, M. L., J. P. Prestemon, C. J. McClean, and J. Touza. 2015. Human-ignited wildfire patterns and responses to policy shifts. Applied Geography 56:164–176. https://doi.org/10.1016/j.apgeog.2014.11.025

Chas-Amil, M. L., J. Touza, and J. P. Prestemon. 2010. Spatial distribution of human-caused forest fires in Galicia (NW Spain). WIT Transactions on Ecology and the Environment 137:247–258. https://doi.org/10.2495/FIVA100221

Chausson, A., B. Turner, D. Seddon, N. Chabaneix, C. A. J. Girardin, V. Kapos, I. Key, D. Roe, A. Smith, S. Woroniecki, and N. Seddon. 2020. Mapping the effectiveness of nature-based solutions for climate change adaptation. Global Change Biology 26(11):6134–6155. https://doi.org/10.1111/gcb.15310

Cohen-Shacham, E., A. Andrade, J. Dalton, N. Dudley, M. Jones, C. Kumar, S. Maginnis, S. Maynard, C. R. Nelson, F. G. Renaud, R. Welling, and G. Walters. 2019. Core principles for successfully implementing and upscaling nature-based solutions. Environmental Science and Policy 98:20–29. https://doi.org/10.1016/j.envsci.2019.04.014

Cohen-Shacham, E., G. Walters, C. Janzen, and S. Maginnis. 2016. Nature-based solutions to address societal challenges. IUCN, Gland, Switzerland. https://doi.org/10.2305/IUCN.CH.2016.13.en

de Castro-Pardo, M., F. Pérez-Rodríguez, J. M. Martín-Martín, and J. C. Azevedo. 2019. Modelling stakeholders' preferences to pinpoint conflicts in the planning of transboundary protected areas. Land Use Policy 89:104233. https://doi.org/10.1016/j.landusepol.2019.104233

Depietri, Y., and D. E. Orenstein. 2020. Managing fire risk at the wildland-urban interface requires reconciliation of tradeoffs between regulating and cultural ecosystem services. Ecosystem Services 44:101108. https://doi.org/10.1016/j.ecoser.2020.101108

Díaz, S., J. Settele, E. S. Brondízio, H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, and A. Pfa. 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES, Bonn, Germany. https://doi.org/10.5281/zenodo.3553579

Ding, Y., R. Zang, S. G. Letcher, S. Liu, and F. He. 2012. Disturbance regime changes the trait distribution, phylogenetic structure and community assembly of tropical rain forests. Oikos 121(8):1263–1270. https://doi.org/10.1111/j.1600-0706.2011.19992.x

Doerr, S. H., and C. Santín. 2016. Global trends in wildfire and its impacts: perceptions versus realities in a changing world. Philosophical Transactions of the Royal Society B: Biological Sciences 371:20150345. https://doi.org/10.1098/rstb.2015.0345

do Rosário, I. T., R. Rebelo, U. Caser, L. Vasconcelos, and M. Santos-Reis. 2019. Valuation of ecosystem services by stakeholders operating at different levels: insights from the Portuguese cultural montado landscape. Regional Environmental Change 19(8):2173–2185. https://doi.org/10.1007/s10113-019-01527-2

Ebbert, D. 2019. chisq.posthoc.test: a post hoc analysis for Pearson's chi-squared test for count. R Foundation for Statistical Computing, Vienna, Austria. https://cran.r-project.org/package=chisq.posthoc.test

European Commission. 2015. Towards an EU research and innovation policy agenda for nature-based solutions and re-naturing cities: final report of the Horizon 2020 expert group on 'Nature-based solutions and re-naturing cities.' European Commission, Brussels, Belgium. https://op.europa.eu/en/publication-detail/-/publication/fb117980-d5aa-46df-8edc-af367cddc202

European Commission. 2022. Key policy objectives of the new CAP. The ten key objectives. European Commission, Brussels, Belgium. https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/new-cap-2023-27/key-policy-objectives-new-cap_en

Fernandes, P. M. 2013. Fire-smart management of forest landscapes in the Mediterranean basin under global change. Landscape and Urban Planning 110(1):175–182. https://doi.org/10.1016/j.landurbplan.2012.10.014

Fernandes, P. M. 2022. Make Europe's forests climate-smart and fire-smart. Nature 609:32. https://doi.org/10.1038/d41586-022-02318-2

Fernandes, P. M., G. M. Delogu, V. Leone, and D. Ascoli. 2020. Wildfire policies contribution to foster extreme wildfires. Pages 187–200 in F. Tedim, V. Leone, and T. K. McGee, editors. Extreme wildfire events and disasters: root causes and new management strategies. Elsevier, Amsterdam, The Netherlands. https://doi.org/10.1016/B978-0-12-815721-3.00010-2

García-Llorente, M., P. A. Harrison, P. Berry, I. Palomo, E. Gómez-Baggethun, I. Iniesta-Arandia, C. Montes, D. García del Amo, and B. Martín-López. 2018. What can conservation strategies learn from the ecosystem services approach? Insights from ecosystem assessments in two Spanish protected areas. Biodiversity and Conservation 27(7):1575–1597. https://doi.org/10.1007/s10531-016-1152-4

Giglio, L., L. Boschetti, D. P. Roy, M. L. Humber, and C. O. Justice. 2018. The Collection 6 MODIS burned area mapping algorithm and product. Remote Sensing of Environment 217:72–85. https://doi.org/10.1016/j.rse.2018.08.005

Hamilton, M., and J. Salerno. 2020. Cognitive maps reveal diverse perceptions of how prescribed fire affects forests and communities. Frontiers in Forests and Global Change 3. https://doi.org/10.3389/ffgc.2020.00075

Hirsch, K., V. Kafka, C. Tymstra, R. McAlpine, B. Hawkes, H. Stegehuis, S. Quintilio, S. Gauthier, and K. Peck. 2001. Fire-smart forest management: a pragmatic approach to sustainable forest management in fire-dominated ecosystems. Forestry Chronicle 77(2):357–363. https://doi.org/10.5558/tfc77357-2

Instituto da Conservação da Natureza e das Florestas (INCF). 2020. Incêndios Rurais. INCF, Lisboa, Portugal. https://www.icnf.pt/florestas/gfr/gfrgestaoinformacao/dfciinformacaocartografica

International Union for the Conservation of Nature (IUCN). 2020. IUCN global standard for nature-based solutions. A user-friendly framework for the verification, design and scaling up of NbS. First edition. IUCN, Gland, Switzerland. https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf

Kark, S., N. Levin, H. S. Grantham, and H. P. Possingham. 2009. Between-country collaboration and consideration of costs increase conservation planning efficiency in the Mediterranean Basin. Proceedings of the National Academy of Sciences 106 (36):15368–15373. https://doi.org/10.1073/pnas.0901001106

Keeley, J. E., and C. J. Fotheringham. 2000. Role of fire in regeneration from seed. Pages 311–330 in M. Fenner, editor. Seeds: the ecology of regeneration in plant communities. CABI, Wallingford, UK. https://doi.org/10.1079/9780851994321.0311

Keesstra, S., J. Nunes, A. Novara, D. Finger, D. Avelar, Z. Kalantari, and A. Cerdà. 2018. The superior effect of nature-based solutions in land management for enhancing ecosystem services. Science of the Total Environment 610–611:997–1009. https://doi.org/10.1016/j.scitotenv.2017.08.077

Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel. 2006. World map of the Köppen-Geiger climate classification updated. Meteorologische Zeitschrift 15(3):259–263. https://doi.org/10.1127/0941-2948/2006/0130

Lasanta, T., J. Arnáez, N. Pascual, P. Ruiz-Flaño, M. P. Errea, and N. Lana-Renault. 2017. Space–time process and drivers of land abandonment in Europe. Catena 149:810–823. https://doi.org/10.1016/j.catena.2016.02.024

Lecina-Diaz, J., M.-L. Chas-Amil, N. Aquilué, Â. Sil, L. Brotons, A. Regos, and J. Touza. 2023. Incorporating fire-smartness into agricultural policies minimises suppression costs and ecosystem services damages from wildfires. Journal of Environmental Management, in press. https://doi.org/10.1101/2023.01.20.524753

Lecina-Diaz, J., J. Martínez-Vilalta, A. Alvarez, M. Banqué, J. Birkmann, D. Feldmeyer, J. Vayreda, and J. Retana. 2021. Characterizing forest vulnerability and risk to climate-change hazards. Frontiers in Ecology and the Environment 19(2):126–133. https://doi.org/10.1002/fee.2278

Mateus, P., and P. M. Fernandes. 2014. Forest fires in Portugal: dynamics, causes and policies. Pages 97-115 in F. Reboredo, editor. Forest context and policies in Portugal. Springer International, Cham, Switzerland. https://doi.org/10.1007/978--3-319-08455-8_4

McCaffrey, S., J. J. Moghaddas, and S. L. Stephens. 2008. Different interest group views of fuels treatments: Survey results from fire and fire surrogate treatments in a Sierran mixed conifer forest, California, USA. International Journal of Wildland Fire 17(2):224–233. https://doi.org/10.1071/WF07005

McCarthy, N., N. S. Bentsen, I. Willoughby, and P. Balandier. 2011. The state of forest vegetation management in Europe in the 21st century. European Journal of Forest Research 130(1):7–16. https://doi.org/10.1007/s10342-010-0429-5

Mierauskas, P., and P. Pereira. 2013. Stakeholders perception about prescribed fire use in Lithuania. First results. FLAMMA 4:156-161.

Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and human well-being: synthesis. Island, Washington, D.C., USA. https://www.millenniumassessment.org/documents/document.356.aspx.pdf

Mirra, I. M., T. M. Oliveira, A. M. Barros, and P. M. Fernandes. 2017. Fuel dynamics following fire hazard reduction treatments in blue gum (*Eucalyptus globulus*) plantations in Portugal. Forest Ecology and Management 398:185-195. https://doi.org/10.1016/j.foreco.2017.05.016

Morán-Ordóñez, A., R. Bugter, S. Suárez-Seoane, E. de Luis, and L. Calvo. 2013. Temporal changes in socio-ecological systems and their impact on ecosystem services at different governance scales: a case study of heathlands. Ecosystems 16:765–782. https://doi.org/10.1007/s10021-013-9649-0

Moreira, F., D. Ascoli, H. Safford, M. A. Adams, J. M. Moreno, J. M. C. Pereira, F. X. Catry, J. Armesto, W. Bond, M. E. González, T. Curt, N. Koutsias, L. McCaw, O. Price, J. G. Pausas, E. Rigolot, S. Stephens, C. Tavsanoglu, V. R. Vallejo, B. W. Van Wilgen, G. Xanthopoulos, and P. M. Fernandes. 2020. Wildfire management in Mediterranean-type regions: paradigm change needed. Environmental Research Letters 15(1):011001. https://doi.org/10.1088/1748-9326/ab541e

Moreira, F., O. Viedma, M. Arianoutsou, T. Curt, N. Koutsias, E. Rigolot, A. Barbati, P. Corona, P. Vaz, G. Xanthopoulos, F. Mouillot, and E. Bilgili. 2011. Landscape - wildfire interactions in southern Europe: implications for landscape management. Journal of Environmental Management 92(10):2389–2402. https://doi.org/10.1016/j.jenvman.2011.06.028

Moritz, M. A., E. Batllori, R. A. Bradstock, A. M. Gill, J. Handmer, P. F. Hessburg, J. Leonard, S. McCaffrey, D. C. Odion, T. Schoennagel, and A. D. Syphard. 2014. Learning to coexist with wildfire. Nature 515(7525):58–66. https://doi.org/10.1038/nature13946

Oliveira, T. M., A. M. G. Barros, A. A. Ager, and P. M. Fernandes. 2016. Assessing the effect of a fuel break network to reduce burnt area and wildfire risk transmission. International Journal of Wildland Fire 25(6):619. https://doi.org/10.1071/WF15146

Pais, S., N. Aquilué, J. Campos, Â. Sil, B. Marcos, F. Martínez-Freiría, J. Domínguez, L. Brotons, J. P. Honrado, and A. Regos. 2020. Mountain farmland protection and fire-smart management jointly reduce fire hazard and enhance biodiversity and carbon sequestration. Ecosystem Services 44:101143. https://doi.org/10.1016/j.ecoser.2020.101143

Palacios-Agundez, I., B. Fernández de Manuel, G. Rodrí;guez-Loinaz, L. Peña, I. Ametzaga-Arregi, J. G. Alday, I. Casado-Arzuaga, I. Madariaga, X. Arana, and M. Onaindia. 2014. Integrating stakeholders' demands and scientific knowledge on ecosystem services in landscape planning. Landscape Ecology 29 (8):1423–1433. https://doi.org/10.1007/s10980-014-9994-1

Palaiologou, P., K. Kalabokidis, A. Troumbis, M. A. Day, M. Nielsen-Pincus, and A. A. Ager. 2021. Socio-ecological perceptions of wildfire management and effects in Greece. Fire 4 (2):18. https://doi.org/10.3390/fire4020018

Pausas, J. G., and J. E. Keeley. 2019. Wildfires as an ecosystem service. Frontiers in Ecology and the Environment 17:289-295. https://doi.org/10.1002/fee.2044

Pausas, J. G., J. Llovet, A. Rodrigo, and R. Vallejo. 2008. Are wildfires a disaster in the Mediterranean basin? – a review. International Journal of Wildland Fire 17:713–723. https://doi.org/10.1071/WF07151

Pereira, P., P. Mierauskas, and A. Novara. 2016. Stakeholders' perceptions about fire impacts on Lithuanian protected areas. Land Degradation and Development 27(4):871–883. https://doi.org/10.1002/ldr.2290

R Core Team. 2020. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/

Randerson, J. T., Y. Chen, G. R. van der Werf, B. M. Rogers, and D. C. Morton. 2012. Global burned area and biomass burning emissions from small fires. Journal of Geophysical Research G: Biogeosciences 117(4). https://doi.org/10.1029/2012JG002128

Rauschmayer, F., S. van den Hove, and T. Koetz. 2009. Participation in EU biodiversity governance: how far beyond rhetoric? Environment and Planning C: Government and Policy 27(1):42–58. https://doi.org/10.1068/c0703j

Reed, M. S. 2008. Stakeholder participation for environmental management: a literature review. Biological Conservation 141 (10):2417–2431. https://doi.org/10.1016/j.biocon.2008.07.014

Regos, A. 2022. Nature-based solutions in an era of mega-fires. Nature 607:449. https://doi.org/10.1038/d41586-022-01955-x

Regos, A., M. Ninyerola, G. Moré, and X. Pons. 2015. Linking land cover dynamics with driving forces in mountain landscape of the Northwestern Iberian Peninsula. International Journal of Applied Earth Observation and Geoinformation 38:1–14. https://doi.org/10.1016/j.jag.2014.11.010

Roces-Díaz, J. V., C. Santín, J. Martínez-Vilalta, and S. H. Doerr. 2021. A global synthesis of fire effects on ecosystem services of forests and woodlands. Frontiers in Ecology and the Environment 20:170-178. https://doi.org/10.1002/fee.2349

Ryan, K. C., E. E. Knapp, and J. M. Varner. 2013. Prescribed fire in North American forests and woodlands: history, current practice, and challenges. Frontiers in Ecology and the Environment 11:e15-e24. https://doi.org/10.1890/120329

San-Miguel-Ayanz, J., D. Oom, T. Artes, D. X. Viegas, P. Fernandes, N. Faivre, S. Freire, P. Moore, F. Rego, and M. Castellnou. 2020. Forest fires in Portugal in 2017. Pages ?? in A. Casajus Valles, M. Marin Ferrer, K. Poljanšek, and I. Clark, editors. Science for disaster risk management 2020: acting today, protecting tomorrow. Publications Office of the European Union, Luxembourg.

Schultz, C. A., M. P. Thompson, and S. M. McCaffrey. 2019. Forest Service fire management and the elusiveness of change. Fire Ecology 15:13. https://doi.org/10.1186/s42408-019-0028-x

Seddon, N., A. Chausson, P. Berry, C. A. J. Girardin, A. Smith, and B. Turner. 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B: Biological Sciences 375:1794. https://doi.org/10.1098/rstb.2019.0120

Sil, Â., F. Fonseca, J. Gonçalves, J. Honrado, C. Marta-Pedroso, J. Alonso, M. Ramos, and J. C. Azevedo. 2017. Analysing carbon sequestration and storage dynamics in a changing mountain landscape in Portugal: insights for management and planning. International Journal of Biodiversity Science, Ecosystem Services and Management 13(2):82–104. https://doi.org/10.1080/21513732.2017.1297331

Silva, J. M. N., M. V. Moreno, Y. Le Page, D. Oom, I. Bistinas, and J. M. C. Pereira. 2019. Spatiotemporal trends of area burnt in the Iberian Peninsula, 1975–2013. Regional Environmental Chang 19(2):515–527. https://doi.org/10.1007/s10113-018-1415-6

Smit, I. P. J., M. Joubert, K. Smith, N. van Wilgen, T. Strydom, J. Baard, and M. Herbst. 2022 Fire as friend or foe: the role of scientists in balancing media coverage of fires in National Parks. African Journal of Range and Forage Science 39:136-147. https://doi.org/10.2989/10220119.2021.1991473

Snider, G., P. J. Daugherty, and D. Wood. 2006. The irrationality of continued fire suppression: an avoided cost analysis of fire hazard reduction treatments versus no treatment. Journal of Forestry 104(8):431-437. https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1172&context=barkbeetles

Tedim, F., V. Leone, and G. Xanthopoulos. 2016. A wildfire risk management concept based on a social-ecological approach in the European Union: Fire Smart Territory. International Journal of Disaster Risk Reduction 18:138–153. https://doi.org/10.1016/j.ijdrr.2016.06.005

Tedim, F., R. Remelgado, C. Borges, S. Carvalho, and J. Martins. 2013. Exploring the occurrence of mega-fires in Portugal. Forest Ecology and Management 294:86–96. https://doi.org/10.1016/j.foreco.2012.07.031

Thompson, M. P., F. Rodríguez y Silva, D. E. Calkin, and M. S. Hand. 2017. A review of challenges to determining and demonstrating efficiency of large fire management. International Journal of Wildland Fire 26(7):562-573. https://doi.org/10.1071/WF16137

Toman, E., B. Shindler, S. McCaffrey, and J. Bennett. 2014. Public acceptance of wildland fire and fuel management: panel responses in seven locations. Environmental Management 54(3):557–570. https://doi.org/10.1007/s00267-014-0327-6

Turner, M. G. 2010. Disturbance and landscape dynamics in a changing world. Ecology 91(10):2833–2849. https://doi.org/10.1890/10-0097.1

van Lierop, P., E. Lindquist, S. Sathyapala, and G. Franceschini. 2015. Global forest area disturbance from fire, insect pests, diseases and severe weather events. Forest Ecology and Management 352:78–88. https://doi.org/10.1016/j.foreco.2015.06.010

Varela, E., J. B. Jacobsen, and M. Soliño. 2014. Understanding the heterogeneity of social preferences for fire prevention management. Ecological Economics 106:91–104. https://doi.org/10.1016/j.ecolecon.2014.07.014

Vukomanovic, J., and T. Steelman. 2019. A systematic review of relationships between mountain wildfire and ecosystem services. Landscape Ecology 34(5):1179–1194. https://doi.org/10.1007/s10980-019-00832-9

World Economic Forum (WEF). 2020. Nature risk rising: why the crisis engulfing Nature matters for business and the economy. World Economic Forum, Geneva, Switzerland. https://www.weforum.org/reports/nature-risk-rising-why-the-crisis-engulfing-nature-matters-for-business-and-the-economy/

Wei, T., and V. Simko. 2017. R package corrplo: visualization of a correlation matrix. Version 0.84. R Foundation for Statistical Computing, Vienna, Austria. https://github.com/taiyun/corrplot

Wiens, J. A., and D. Bachelet. 2010. Matching the multiple scales of conservation with the multiple scales of climate change. Conservation Biology 24(1):51–62. https://doi.org/10.1111/j.1523-1739.2009.01409.x

Williams, J., D. Albright, A. A. Hoffmann, A. Eritsov, P. F. Moore, J. C. Mendes De Morais, M. Leonard, J. San Miguel-Ayanz, G. Xanthopoulos, and I. P. van Lierop. 2011. Findings and implications from a coarse-scale global assessment of recent selected mega-fires. FAO, Rome, Italy. https://www.fao.org/forestry/32063-0613ebe395f6ff02fdecd13b7749f39ea.pdf

Wimberly, M. C., M. A. Cochrane, A. D. Baer, and K. Pabst. 2009. Assessing fuel treatment effectiveness using satellite imagery and spatial statistics. Ecological Applications 19:1377-1384. https://doi.org/10.1890/08-1685.1

Wolmer, W. 2003. Transboundary protected area governance: tensions and paradoxes. Governance An International Journal of Policy and Administration September:1-13.

Wunder, S., D. E. Calkin, V. Charlton, S. Feder, I. Martínez de Arano, P. Moore, F. Rodríguez y Silva, L. Tacconi, and C. Vega-García. 2021. Resilient landscapes to prevent catastrophic forest fires: socioeconomic insights towards a new paradigm. Forest Policy and Economics 128:102458. https://doi.org/10.1016/j.forpol.2021.102458

Stakeholders’ perceptions support Nature-Based Solutions for wildfire management in two Iberian Biosphere Reserves

Appendix

Table A1. Summary of the fire-management approaches considered (name, definition, stakeholders involved, use in the study areas and example).

Type of management	Definition	Stakeholders’ groups involved or affected	Usage in the study areas	Example
Changing forest composition	Vegetation type conversion based on changing forest species composition to less flammable and fire-susceptible stands	Forest actors and civil protection	Low/very low	Replacement of conifer by broadleaved native species
Fuel breaks	Promoting and maintaining fuel-treated linear strips that create opportunities for safe and effective firefighting operations. Fuel loads are reduced and vertical and horizontal fuel continuity are disrupted	Forest actors and civil protection	Moderate	Fuel break networks Treatments along power lines, roads and trails
Shrub and understory clearing	Removal of understory and shrub vegetation to reduce fuel load and continuity	Forest actors and civil protection	Moderate	Motomanual understory cutting
Prescribed fire	Technical application of fire under specified weather conditions to reduce fuel load and continuity	Forest actors and civil protection (fire-fighters)	Low	Prescribed burning in shrubland
Mechanical treatments	Use of machinery to reduce fuel load and continuity	Forest actors and civil protection	Low	Thinning (tree density reduction), tree pruning (increasing canopy base height)
Chemical treatments	Use of chemical substances to put out fires	Forest actors and civil protection (fire-fighters)	Moderate	Use of chemical fire retardants
Promoting agriculture and livestock	Increasing agricultural and livestock areas to increase landscape heterogeneity and reduce fire hazard	Local development; Government	Low	Promotion of “Cachena” cattle (local breed cattle)
Introducing large herbivores	Introducing local or native herbivor species that reduce fuel load by feeding	Government; Local development; Nature conservation	Low	Promotion of “Cachena” cattle

Table A2. Number of respondents in each of the sectors and study areas. Note that some stakeholders belong to more than one sector so that the total is higher than the number of surveys answered (129 and 114, respectively).

	Study areas		
Sectors	Gerês - Xurés	Meseta Ibérica	Whole region
Forest actors and civil protection	27	9	19
Government	5	4	5
Local development	11	10	5
Nature conservation	9	5	3
Research	3	1	8
Other	2	1	2
Total	**57**	**30**	**42**

Table A3. Number of answers in the Fire section grouped by study areas (Gerês-Xurés, Meseta Ibérica and Whole region - not directly associated with the two study areas but influential in the region). Percentage of respondents is the percentage over all the respondents (i.e., 114). Note that questions 1.1, 1.4 and 1.5 are multiple choice, so that the total number of answers can be higher than the total number of questionnaires answered (114), and the total percentage can be higher than 100%.

	Study areas			
1.1. What’s your perception about fire?	Gerês - Xurés	Meseta Ibérica	Whole region	Percentage of respondents
Fire has catastrophic effects on landscape and human lives	26	15	15	**49.1**
Fire must be suppressed under any circumstance	1	5	0	**5.3**
Fire is an ecological process necessary to ecosystems	18	12	12	**36.8**
Fire must be managed by humans	42	18	28	**77.2**
Total question 1.1	**87**	**50**	**55**	
1.2. How has fire regime changed in the study areas during the last 30 years?				
Less fires with less intensity/severity	2	0	2	**3.5**
Less fires with more intensity/severity	31	3	15	**43.0**
More fires with less intensity/severity	2	5	1	**7.0**
More fires with more intensity/severity	16	20	17	**46.5**
Total question 1.2	**51**	**28**	**35**	
1.3. How will fire regime change in the study areas the future 30-40 years (in absence of management)?				
Less fires with less intensity/severity	4	2	0	**5.3**
Less fires with more intensity/severity	27	5	12	**38.6**
More fires with less intensity/severity	1	0	4	**4.4**
More fires with more intensity/severity	19	21	19	**51.8**
Total question 1.3	**51**	**28**	**35**	
1.4. Which are the main causes of large wildfires?				
Climate change	22	16	16	**47.4**
Rural abandonment	47	26	32	**92.1**
Intensification of forest monocultures	17	12	8	**32.4**
Lack of management of forest monocultures	22	7	17	**40.4**

Fire extinction systems inefficient and/or with lack of resources	7	6	4	**14.9**
Fire prevention systems inefficient and/or with lack of resources	28	15	17	**52.6**
Fire extinction systems efficient in low intensity fires, but inefficient in high intensity fires	14	4	10	**24.6**
Lack of collaboration/coordination between landscape management (prevention) and fire (extinction) organizations	26	11	16	**46.5**
Absence of an integrated fire management policy	28	17	20	**57.0**
Arson	3	0	2	**4.4**
Other	4	1	2	**6.1**
Lack of collaboration/coordination between countries and local people	4	0	0	**3.5**
Total question 1.4	**222**	**115**	**144**	
1.5. How can large wildfires be prevented?				
Increasing fire extinction resources	4	4	7	**13.2**
Increasing fire prevention resources	38	21	20	**69.3**
Increasing the professionalism of fire-fighters	14	10	8	**28.1**
Landscape management to create more fire-resilient and resistant landscapes	37	18	23	**68.4**
Integrated fire management policies, balancing the distribution of resources and following the main land management objectives	36	19	28	**72.8**
Increasing collaboration/coordination at local and international levels	2	1	1	**3.5**
Reducing arson ignitions by increasing punishment or social investments	2	1	0	**2.6**
Economic viable rural opportunities	0	1	1	**1.8**
Other	0	0	1	**0.9**
Total question 1.5	**133**	**75**	**89**	

Table A4. Number of answers in the Landscape section grouped by study areas (Gerês-Xurés, Meseta Ibérica and Whole region - not directly associated with the two study areas but influential in the region).

	Study areas			
2.1. How has landscape changed in the study areas for the last 30 years?	Gerês - Xurés	Meseta Ibérica	Whole region	Percentage of respondents
Rural abandonment, with a consequent increase of forest and shrubland areas	38	23	32	**81.6**
Decrease in forests and increase in shrublands	13	4	2	**16.7**
Increase in agricultural areas and forest pastures, and decrease in shrublands and forests	0	1	1	**1.8**
Total question 2.1	**51**	**28**	**35**	
2.2. How will landscape change in the study areas the future 30-40 years (in absence of management)?				
Rural abandonment, with a consequent increase of forest and shrubland areas	31	18	28	**67.5**
Decrease in forests and increase in shrublands	17	9	6	**28.1**
Increase in agricultural areas and forest pastures, and decrease in shrublands and forests	3	1	1	**4.4**
Total question 2.2	**51**	**28**	**35**	
2.3. How should landscape change in the study				

areas?				
Towards an agricultural landscape	1	0	1	**1.8**
Towards a landscape with forests more resistant to fire	7	3	4	**12.3**
Towards a re-naturalized landscape (rewilding), and with more forest	4	1	2	**6.1**
Towards a landscape with a combination of the above-mentioned scenarios	39	24	28	**79.8**
Total question 2.3	**51**	**28**	**35**	

Table A5. Number of answers in the Fire-management section grouped by study areas (Gerês-Xurés, Meseta Ibérica and Whole region - not directly associated with the two study areas but influential in the region). Percentage of respondents is the percentage over all the respondents (i.e., 114). Note that question 3.6 is multiple choice, so that the total number of answers can be higher than the total number of questionnaires answered (114), and the total percentage can be higher than 100%.

	Study areas			
3.6. How would you value the success in preventing large wildfires?	Gerês - Xurés	Meseta Ibérica	Whole region	Percentage of respondents
Contribution to biodiversity conservation	32	21	22	**65.8**
Creation of new jobs	11	7	12	**26.3**
Maintenance of the sustainable provision of ecosystem services	24	19	15	**50.9**
Reduction of fire severity	33	18	28	**69.3**
Reduction of the impacts on people and properties	30	13	14	**50**
Reduction of total burned area	33	13	15	**53.5**
I don’t know/not applicable	1	0	0	**0.9**
Total question 3.6	**164**	**91**	**106**	
3.7. How do you value the transboundary collaboration/coordination between landscape management and fire prevention organizations?				
Inadequate	32	13	11	**49.1**
Nonexistent	10	6	4	**17.5**
Adequate	4	2	6	**10.5**
Very good	0	4	0	**3.5**
I don’t know/not applicable	5	3	14	**19.3**
Total question 3.7	**51**	**28**	**35**	
3.8. How do you value the transboundary collaboration/coordination between fire extinction organizations?				
Inadequate	30	12	12	**47.4**
Nonexistence	8	5	4	**14.9**
Adequate	7	5	8	**17.5**
Very good	1	3	1	**4.4**
I don’t know/not applicable	5	3	10	**15.8**
Total question 3.8	**51**	**28**	**35**	

Table A6. Results of the Chi-squared tests (*Chi-squared* and *p-value*) testing the differences among sectors and study areas on the survey answers for the sections of fire (section 1) and changes in the landscape (section 2). Significant values are shown in bold.

	Sectors		Study areas	
Question	χ 2	*p value*	χ 2	*p value*
1.1. What's your perception about fire?	16.2	0.178	14.5	**0.027**
1.2. How has the fire regime changed in the study areas during the last 30 years?	19.1	0.086	26.6	**0.000**
1.3. How will the fire regime change in the study areas in the future 30-40 years (in absence of management)?	25.2	**0.014**	22.7	**0.002**
1.4. Which are the main causes of large wildfires?	43.0	0.512	19.1	0.651
1.5. How can they be prevented?	34.0	0.569	15.7	0.653
2.1. How has the landscape changed in the study areas for the last 30 years?	6.8	0.561	9.9	**0.030**
2.2. How will the landscape change in the study areas in the future 30-40 years (in absence of management)?	11.0	0.184	5.2	0.263
2.3. How should the landscape change in the study areas?	8.5	0.777	6.8	0.359

Table A7. Bonferroni posthoc analysis (*p-value*) for the significant questions in Table A5. Significant values are shown in bold.

Question	Posthoc (bonferroni)	*p value*
SECTORS		
1.3	Less fires with more intensity/severity - Forest actors & civil protection	**0.01**
STUDY AREAS		
1.1	Fire must be suppressed under any circumstance – Meseta Ibérica	**0.01**
1.2	Less fires with more intensity/severity – Gerês-Xurés	**0.00**
1.2	Less fires with more intensity/severity – Meseta Ibérica	**0.00**
1.2	More fires with more intensity/severity – Gerês-Xurés	**0.00**
1.3	Less fires with more intensity/severity – Gerês-Xurés	**0.00**
1.3	More fires with more intensity/severity – Gerês-Xurés	**0.00**
2.1	Decrease in forests and increase in shrublands – Gerês-Xurés	**0.05**

Table A8. Results of the Chi-squared tests (*Chi-squared* and *p-value*) testing the differences among sectors and study areas on the survey answers for the questions 3.1. Significant values are shown in bold.

	Sectors		Study areas	
Question	2	*p value*	2	*p value*
3.1.1. Considering the current availability of resources and in the absence of extreme weather conditions, how do you value the firefighting capacity? Shrubland fires in gentle slopes	30.2	**0.017**	13.2	0.099
3.1.2. Considering the current availability of resources and in the absence of extreme weather conditions, how do you value the firefighting capacity? Shrubland fires in steep slopes	30.3	**0.016**	18.6	**0.013**
3.1.3. Considering the current availability of resources and in the absence of extreme weather conditions, how do you value the firefighting capacity? Forest fires in gentle slopes	28.0	**0.028**	12.4	0.126
3.1.4. Considering the current availability of resources and in the absence of extreme weather conditions, how do you value the firefighting capacity? Forest fires in steep slopes	31.0	**0.012**	9.8	0.269
3.1.5. Considering the current availability of resources and in the absence of extreme weather conditions, how do you value the firefighting capacity? Fires of small and medium size	33.7	**0.009**	9.7	0.286
3.1.6. Considering the current availability of resources and in the absence of extreme weather conditions, how do you value the firefighting capacity? Large fires	14.4	0.564	9.2	0.336
3.1.7. Considering the current availability of resources and in the absence of extreme weather conditions, how do you value the firefighting capacity? Ability to protect assets and people	18.4	0.308	8.9	0.362
3.1.8. Considering the current availability of resources and in the absence of extreme weather conditions, how do you value the firefighting capacity? Accessibility and use of extinction resources	31.2	**0.016**	9.6	0.303
3.1.9. Considering the current availability of resources and in the absence of extreme weather conditions, how do you value the firefighting capacity? Possibility to act without restrictions	35.8	**0.003**	7.6	0.495

Table A9. Bonferroni posthoc analysis (*p-value*) for the significant questions in Table A7. Significant values are shown in bold.

Question	Posthoc (bonferroni)	*p value*
SECTORS		
3.1.1	Nature conservation – inadequate	**0.08**
3.1.2	Forest actors & civil protection – inadequate	0.18
3.1.2	Local development – good	0.22
3.1.3	Forest actors & civil protection – very good	0.44

3.1.4	Forest actors & civil protection – inadequate	0.35
3.1.4	Local development – good	0.40
3.1.5	Nature conservation – inadequate	**0.05**
3.1.5	Local development – very good	**0.01**
3.1.8	Local development – good	**0.01**
3.1.9	Forest actors & civil protection – I don’t know/not applicable	**0.01**
3.1.9	Government – I don’t know/not applicable	0.28
STUDY AREAS		
3.1.2	Adequate – Whole region	**0.04**

Table A10. Results of the Chi-squared tests (*Chi-squared* and *p-value*) testing the differences among sectors and study areas on the survey answers for the questions 3.2-3.8. Significant values are shown in bold.

	Sectors		Study areas	
Question	2	*p value*	2	*p value*
3.2.1. Which type of management is necessary to prevent large wildfires? Changing forest composition to increase resistance to fire	27.1	0.133	19.6	**0.022**
3.2.2. Which type of management is necessary to prevent large wildfires? Increase in fuel breaks	20.2	0.224	16.8	**0.019**
3.2.3. Which type of management is necessary to prevent large wildfires? Shrub and understory clearing	12.4	0.736	5.5	0.745
3.2.4. Which type of management is necessary to prevent large wildfires? Decrease in fuel using prescribed fire	24.5	0.227	10.3	0.414
3.2.5. Which type of management is necessary to prevent large wildfires? Decrease in fuel using mechanical methods	8.7	0.940	9.3	0.328
3.2.6. Which type of management is necessary to prevent large wildfires? Decrease in fuel using chemical methods	19.4	0.522	18.8	**0.029**
3.2.7. Which type of management is necessary to prevent large wildfires? Promoting agriculture and livestock	15.1	0.530	6.8	0.612
3.2.8. Which type of management is necessary to prevent large wildfires? Introducing large herbivores	27.8	0.105	14.3	0.142
3.3.1. Which areas can benefit more depending on the type of management? Changing forest composition to increase resistance to fire	6.9	0.980	6.3	0.642
3.3.2. Which areas can benefit more depending on the type of management? Increase in fuel breaks	15.9	0.457	14.5	0.064

3.3.3. Which areas can benefit more depending on the type of management? Shrub and understory clearing	22.7	0.128	2.2	0.981
3.3.4. Which areas can benefit more depending on the type of management? Decrease in fuel using prescribed fire	14.0	0.616	5.0	0.752
3.3.5. Which areas can benefit more depending on the type of management? Decrease in fuel using mechanical methods	12.5	0.718	2.2	0.980
3.3.6. Which areas can benefit more depending on the type of management? Decrease in fuel using chemical methods	11.9	0.768	6.1	0.657
3.3.7. Which areas can benefit more depending on the type of management? Promoting agriculture and livestock	15.0	0.514	9.2	0.315
3.3.8. Which areas can benefit more depending on the type of management? Introducing large herbivores	7.5	0.970	8.3	0.404
3.4.1. Which ecosystem services can benefit more depending on the type of management? Changing forest composition to increase resistance to fire	19.5	0.719	12.0	0.433
3.4.2. Which ecosystem services can benefit more depending on the type of management? Increase in fuel breaks	18.2	0.806	11.4	0.502
3.4.3. Which ecosystem services can benefit more depending on the type of management? Shrub and understory clearing	15.8	0.914	12.1	0.444
3.4.4. Which ecosystem services can benefit more depending on the type of management? Decrease in fuel using prescribed fire	30.3	0.175	11.9	0.470
3.4.5. Which ecosystem services can benefit more depending on the type of management? Decrease in fuel using mechanical methods	22.4	0.557	8.2	0.782
3.4.6. Which ecosystem services can benefit more depending on the type of management? Decrease in fuel using chemical methods	21.1	0.651	13.5	0.352
3.4.7. Which ecosystem services can benefit more depending on the type of management? Promoting agriculture and livestock	18.9	0.741	13.2	0.346
3.4.8. Which ecosystem services can benefit more depending on the type of management? Introducing large herbivores	17.6	0.852	10.8	0.548
3.5.1. Which ecosystem services can be negatively affected by management? Changing forest composition to increase resistance to fire	17.3	0.857	15.3	0.219
3.5.2. Which ecosystem services can be negatively affected by management? Increase in fuel breaks	36.2	**0.048**	18.0	0.114
3.5.3. Which ecosystem services can be negatively affected by management? Shrub and understory clearing	19.4	0.754	13.2	0.366
3.5.4. Which ecosystem services can be negatively affected by management? Decrease in fuel using prescribed fire	19.7	0.714	15.4	0.226
3.5.5. Which ecosystem services can be negatively affected by management? Decrease in fuel using mechanical methods	20.8	0.659	9.2	0.690
3.5.6. Which ecosystem services can be negatively affected by management? Decrease in fuel using chemical methods	16.3	0.888	21.7	**0.047**
3.5.7. Which ecosystem services can be negatively affected by management? Promoting agriculture and livestock	23.8	0.482	8.4	0.765

3.5.8. Which ecosystem services can be negatively affected by management? Introducing large herbivores	23.9	0.473	10.4	0.594
3.6. How would you value the success in preventing large wildfires?	19.5	0.731	12.8	0.379
3.7. How do you value the transboundary collaboration/coordination between landscape management and fire prevention organizations?	20.4	0.201	30.1	**0.001**
3.8. How do you value the transboundary collaboration/coordination between fire extinction organizations?	28.1	**0.034**	17.7	0.023

Table A11. Bonferroni posthoc analysis (*p-value*) for the significant questions in Table A9. Significant values are shown in bold.

Question	Posthoc (bonferroni)	*p value*
SECTORS		
3.5.2	Forest actors & civil protection – Timber and wood	**0.09**
3.5.2	Local development – Timber and wood	0.18
3.8	Local development – adequate	0.20
3.8	Nature conservation – nonexistent	0.22
STUDY AREAS		
3.2.1	Slightly necessary – Gerês-Xurés	**0.01**
3.2.2	Absolutely necessary – Whole region	**0.03**
3.2.6	Absolutely unnecessary – Whole region	**0.00**
3.5.6	I don't know/not applicable – Whole region	**0.01**
3.7	I don't know/not applicable – Whole region	**0.01**
3.7	Very good – Meseta Ibérica	**0.00**
3.8	Inadequate – Gerês-Xurés	0.07

Questionário FirESmart

O projeto FirESmart (https://firesmartprojectpt.wordpress.com) visa reduzir os impactos do fogo, garantindo a conservação da biodiversidade e a prestação de serviços dos ecossistemas.

As duas áreas de estudo do projeto (Reservas do Gerês-Xurés e Meseta Ibérica) são sistemas sócio-ecológicos, nos quais a sociedade interage com a natureza. Para se ter uma visão completa e integrativa da área, é prioritário avaliar as perspetivas dos diferentes setores do território ao nível dos incêndios florestais, a sua relação com a paisagem e a gestão paisagem-fogo.

As informações coletadas nesta pesquisa serão utilizadas exclusivamente para fins científicos, e por isso, serão tratadas de forma anónima e confidencial. Em nenhum caso os dados pessoais constarão nos resultados da pesquisa, uma vez que estes serão agrupados por setores do território.

Muito obrigado pela sua participação!

Próxima

Página 1 de 6

Figure A1. Questionnaire sent to the stakeholders (Portuguese version). Note that asterisks denote mandatory questions.

1. Fogo

1.1. Qual é a sua percepção em relação ao uso do fogo? (pode selecionar mais de uma opção) *

- [ ] O fogo tem um efeito devastador na paisagem e na vida humana.
- [ ] O fogo deve ser suprimido em qualquer circunstância.
- [ ] O fogo é um processo ecológico necessário para os ecossistemas.
- [ ] O fogo deve ser gerido/controlado pelo Homem.

1.2. Como acha que evoluiu o regime de fogo nos últimos 30 anos nas áreas de estudo (Gerês-Xurés e Meseta Ibérica)? *

- ◯ Cada vez mais incêndios de maior intensidade/severidade.
- ◯ Cada vez mais incêndios, mas de menor intensidade/severidade.
- ◯ Cada vez menos incêndios de menor intensidade/severidade.
- ◯ Cada vez menos incêndios, mas de maior intensidade/severidade.

1.3. Como acha que poderão evoluir os incêndios na área de estudo nos próximos 30-40 anos se nenhuma ação for tomada? *

- ◯ Cada vez mais incêndios de maior intensidade/severidade.
- ◯ Cada vez mais incêndios, mas de menor intensidade/severidade.
- ◯ Cada vez menos incêndios de menor intensidade/severidade.
- ◯ Cada vez menos incêndios, mas de maior intensidade/severidade.

Figure A1. (continued)

1.4. Quais são as principais causas dos grandes incêndios florestais? (pode selecionar mais de uma opção) *

- [ ] As alterações climáticas.
- [ ] O abandono rural.
- [ ] A intensificação de monoculturas florestais.
- [ ] A ausência de gestão das monoculturas florestais.
- [ ] Os sistemas de extinção de fogo pouco eficientes e/ou com poucos recursos.
- [ ] Os sistemas de prevenção de fogo pouco eficientes e/ou com poucos recursos.
- [ ] Os sistemas de extinção de fogo muito eficientes nos incêndios de baixa intensidade, mas não nos de alta intensidade.
- [ ] A falta de colaboração/coordenação entre as organizações de gestão da paisagem (prevenção) e do fogo (extinção).
- [ ] A ausência de uma política de gestão integrada do fogo.
- [ ] Outro: ________

1.5. Como acha que se poderiam evitar? (pode selecionar mais de uma opção) *

- [ ] Com o aumento dos recursos (equipamento e manpower) dedicados à extinção de fogos.
- [ ] Com o aumento dos recursos (equipamento e manpower) dedicados à prevenção de fogos.
- [ ] Com corpos de bombeiros mais profissionalizados.
- [ ] Com uma gestão focada em paisagens mais resilientes e resistentes ao fogo.
- [ ] Através de uma política de gestão integrada do fogo, equilibrada na distribuição de recursos e obedecendo aos objetivos de gestão do território.
- [ ] Outro: ________

Voltar | Próxima | Página 2 de 6

Figure A1. (continued)

2. Paisagem

2.1. Como acha que a paisagem evoluiu nos últimos 30 anos na área de estudo? *

- Abandono agrícola e das atividades silvo-pastoris com aumento da área de mato e floresta.
- Perda de floresta e aumentos de área de mato.
- Aumento de áreas agrícolas e atividades silvo-pastoris e perda de mato e floresta.

2.2. Como acha que a paisagem irá evoluir nos próximos 30-40 anos se nenhuma ação for tomada? *

- Abandono agrícola e das atividades silvo-pastoris com aumentos de zonas de mato e floresta.
- Perda de floresta e aumento de zonas de mato.
- Aumento de áreas agrícolas e atividades silvo-pastoris e perda de mato e floresta.

2.3. Como acha que deveria evoluir? *

- Para uma paisagem agrícola.
- Para uma paisagem com florestas mais resilientes e resistentes ao fogo.
- Para uma paisagem mais florestal e renaturalizada (rewilding).
- Para uma paisagem com a combinação dos cenários anteriores.

Voltar | Próxima | Página 3 de 6

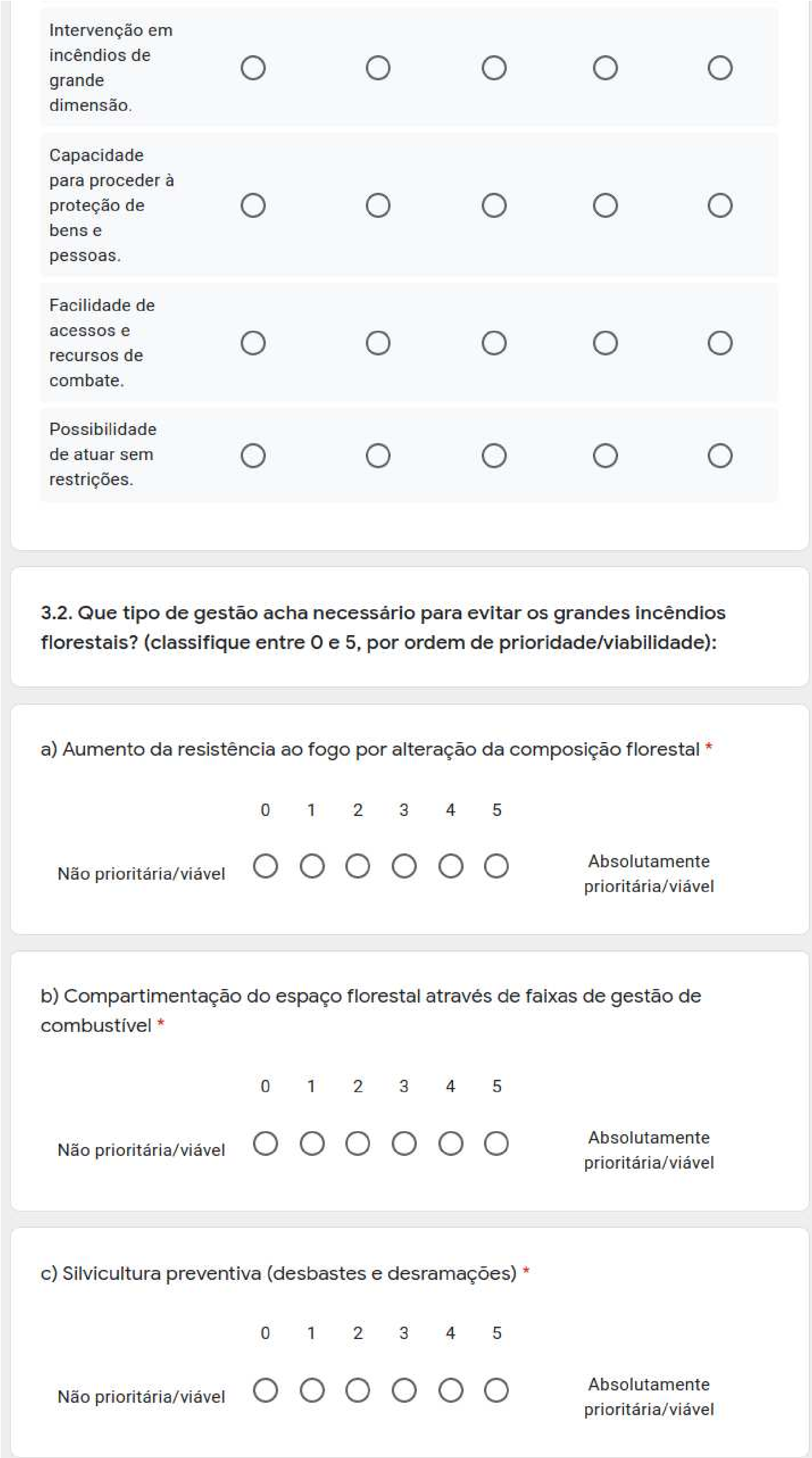
Figure A1. (continued)

3. Gestão da paisagem e do fogo

3.1. Com os meios disponíveis atualmente e em condições meteorológicas não particularmente extremas, qual a capacidade habitual dos corpos de bombeiros para a supressão de fogos? *

	Insuficiente	Suficiente	Boa	Muito boa	Não sei/não aplicável
Intervenção em incêndios de áreas de mato com declives reduzidos.	○	○	○	○	○
Intervenção em incêndios de áreas de mato com declives elevados.	○	○	○	○	○
Intervenção em incêndios de áreas florestais com declives reduzidos.	○	○	○	○	○
Intervenção em incêndios de áreas florestais com declives elevados.	○	○	○	○	○
Intervenção em incêndios de pequena e média dimensão.	○	○	○	○	○

Figure A1. (continued)



Intervenção em incêndios de grande dimensão.	○	○	○	○	○
Capacidade para proceder à proteção de bens e pessoas.	○	○	○	○	○
Facilidade de acessos e recursos de combate.	○	○	○	○	○
Possibilidade de atuar sem restrições.	○	○	○	○	○

3.2. Que tipo de gestão acha necessário para evitar os grandes incêndios florestais? (classifique entre 0 e 5, por ordem de prioridade/viabilidade):

a) Aumento da resistência ao fogo por alteração da composição florestal *

	0	1	2	3	4	5	
Não prioritária/viável	○	○	○	○	○	○	Absolutamente prioritária/viável

b) Compartimentação do espaço florestal através de faixas de gestão de combustível *

	0	1	2	3	4	5	
Não prioritária/viável	○	○	○	○	○	○	Absolutamente prioritária/viável

c) Silvicultura preventiva (desbastes e desramações) *

	0	1	2	3	4	5	
Não prioritária/viável	○	○	○	○	○	○	Absolutamente prioritária/viável

Figure A1. (continued)

d) Redução do combustível com fogo controlado *

	0	1	2	3	4	5	
Não prioritária/viável	○	○	○	○	○	○	Absolutamente prioritária/viável

e) Redução do combustível com métodos motomanuais ou mecânicos *

	0	1	2	3	4	5	
Não prioritária/viável	○	○	○	○	○	○	Absolutamente prioritária/viável

f) Redução do combustível com métodos químicos *

	0	1	2	3	4	5	
Não prioritária/viável	○	○	○	○	○	○	Absolutamente prioritária/viável

g) Fomentar as atividades agrícolas e silvo-pastoris *

	0	1	2	3	4	5	
Não prioritária/viável	○	○	○	○	○	○	Absolutamente prioritária/viável

h) Introdução de grandes herbívoros (Cabra Montesa, Garranos, etc.) *

	0	1	2	3	4	5	
Não prioritária/viável	○	○	○	○	○	○	Absolutamente prioritária/viável

Figure A1. (continued)

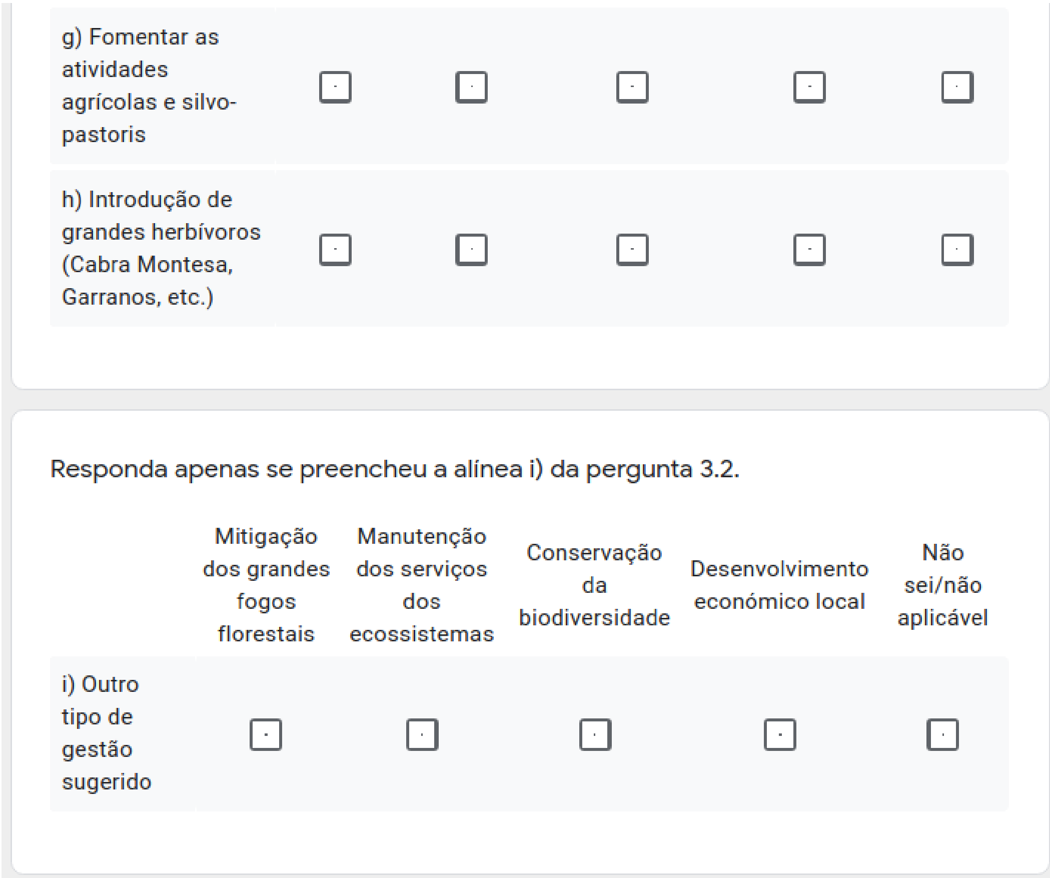
i) Outro tipo de gestão não considerado e que ache necessário (em caso afirmativo, descreva sucintamente o tipo de gestão e classifique entre 0 e 5 por ordem de prioridade/viabilidade).

Sua resposta

3.3. Quais as áreas (colunas) que seriam mais beneficiadas por cada tipo de gestão (linhas)? (pode selecionar mais de uma opção para cada tipo de gestão): *

	Mitigação dos grandes fogos florestais	Manutenção dos serviços dos ecossistemas	Conservação da biodiversidade	Desenvolvimento económico local	Não sei/não aplicável
a) Aumento da resistência ao fogo por alteração da composição florestal	☐	☐	☐	☐	☐
b) Compartimentação do espaço florestal através de faixas de gestão de combustível	☐	☐	☐	☐	☐
c) Silvicultura preventiva (desbastes e desramações)	☐	☐	☐	☐	☐
d) Redução do combustível com fogo controlado	☐	☐	☐	☐	☐
e) Redução do combustível com métodos motomanuais ou mecânicos	☐	☐	☐	☐	☐
f) Redução do combustível com métodos químicos	☐	☐	☐	☐	☐

Figure A1. (continued)



g) Fomentar as atividades agrícolas e silvo-pastoris	☐	☐	☐	☐	☐
h) Introdução de grandes herbívoros (Cabra Montesa, Garranos, etc.)	☐	☐	☐	☐	☐

Responda apenas se preencheu a alínea i) da pergunta 3.2.

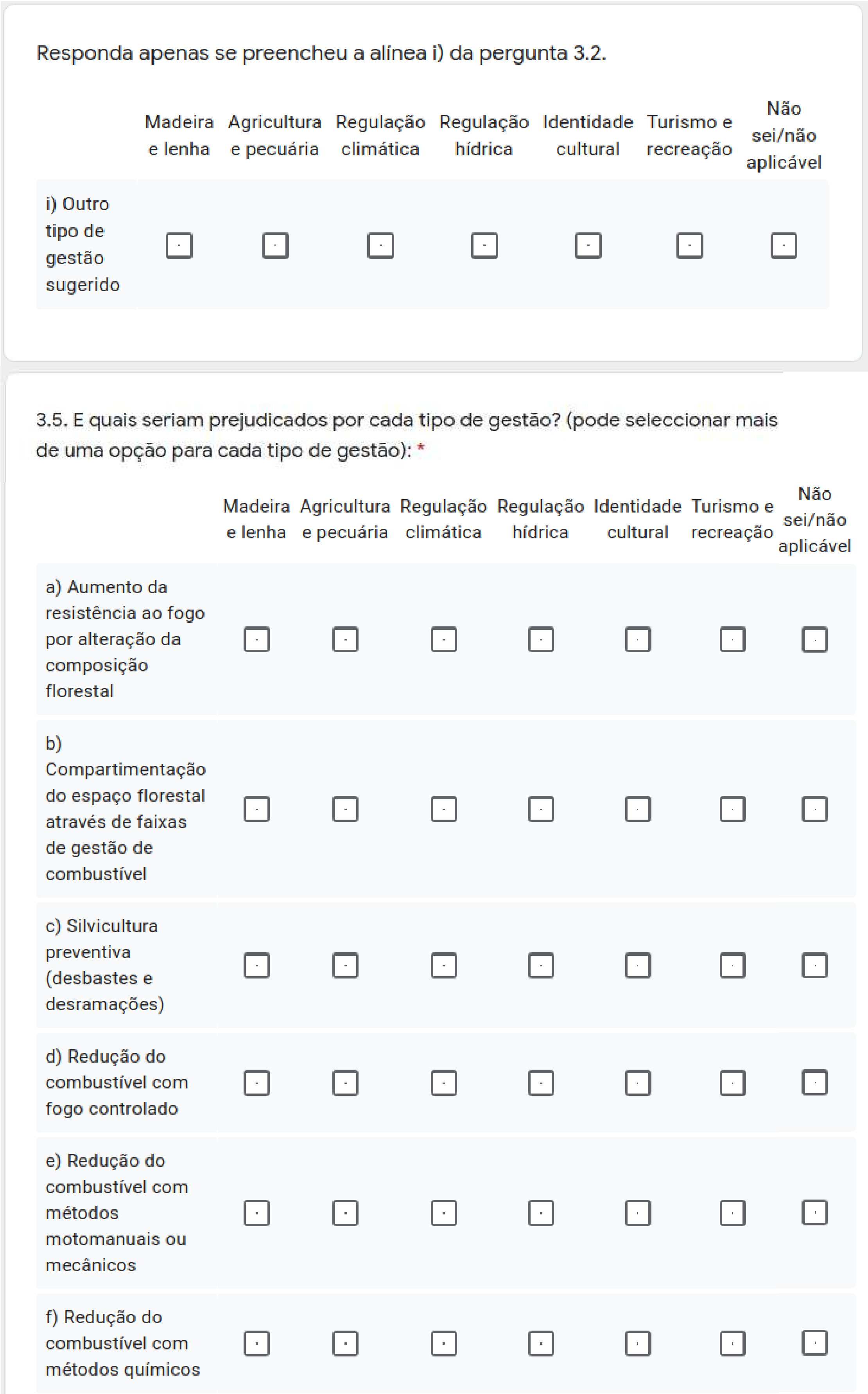
	Mitigação dos grandes fogos florestais	Manutenção dos serviços dos ecossistemas	Conservação da biodiversidade	Desenvolvimento económico local	Não sei/não aplicável
i) Outro tipo de gestão sugerido	☐	☐	☐	☐	☐

Figure A1. (continued)

3.4. Se nos centrarmos nos serviços dos ecossistemas (colunas), quais seriam mais beneficiados por cada tipo de gestão (linhas)? (pode seleccionar mais de uma opção para cada tipo de gestão): *

	Madeira e lenha	Agricultura e pecuária	Regulação climática	Regulação hídrica	Identidade cultural	Turismo e recreação	Não sei/não aplicável
a) Aumento da resistência ao fogo por alteração da composição florestal	☐	☐	☐	☐	☐	☐	☐
b) Compartimentação do espaço florestal através de faixas de gestão de combustível	☐	☐	☐	☐	☐	☐	☐
c) Silvicultura preventiva (desbastes e desramações)	☐	☐	☐	☐	☐	☐	☐
d) Redução do combustível com fogo controlado	☐	☐	☐	☐	☐	☐	☐
e) Redução do combustível com métodos motomanuais ou mecânicos	☐	☐	☐	☐	☐	☐	☐
f) Redução do combustível com métodos químicos	☐	☐	☐	☐	☐	☐	☐
g) Fomentar as atividades agrícolas e silvo-pastoris	☐	☐	☐	☐	☐	☐	☐
h) Introdução de grandes herbívoros (Cabra Montesa, Garranos, etc.)	☐	☐	☐	☐	☐	☐	☐

Figure A1. (continued)



Responda apenas se preencheu a alínea i) da pergunta 3.2.

	Madeira e lenha	Agricultura e pecuária	Regulação climática	Regulação hídrica	Identidade cultural	Turismo e recreação	Não sei/não aplicável
i) Outro tipo de gestão sugerido	☐	☐	☐	☐	☐	☐	☐

3.5. E quais seriam prejudicados por cada tipo de gestão? (pode seleccionar mais de uma opção para cada tipo de gestão): *

	Madeira e lenha	Agricultura e pecuária	Regulação climática	Regulação hídrica	Identidade cultural	Turismo e recreação	Não sei/não aplicável
a) Aumento da resistência ao fogo por alteração da composição florestal	☐	☐	☐	☐	☐	☐	☐
b) Compartimentação do espaço florestal através de faixas de gestão de combustível	☐	☐	☐	☐	☐	☐	☐
c) Silvicultura preventiva (desbastes e desramações)	☐	☐	☐	☐	☐	☐	☐
d) Redução do combustível com fogo controlado	☐	☐	☐	☐	☐	☐	☐
e) Redução do combustível com métodos motomanuais ou mecânicos	☐	☐	☐	☐	☐	☐	☐
f) Redução do combustível com métodos químicos	☐	☐	☐	☐	☐	☐	☐

Figure A1. (continued)

g) Fomentar as atividades agrícolas e silvo-pastoris	☐	☐	☐	☐	☐	☐	☐
h) Introdução de grandes herbívoros (Cabra Montesa, Garranos, etc.)	☐	☐	☐	☐	☐	☐	☐

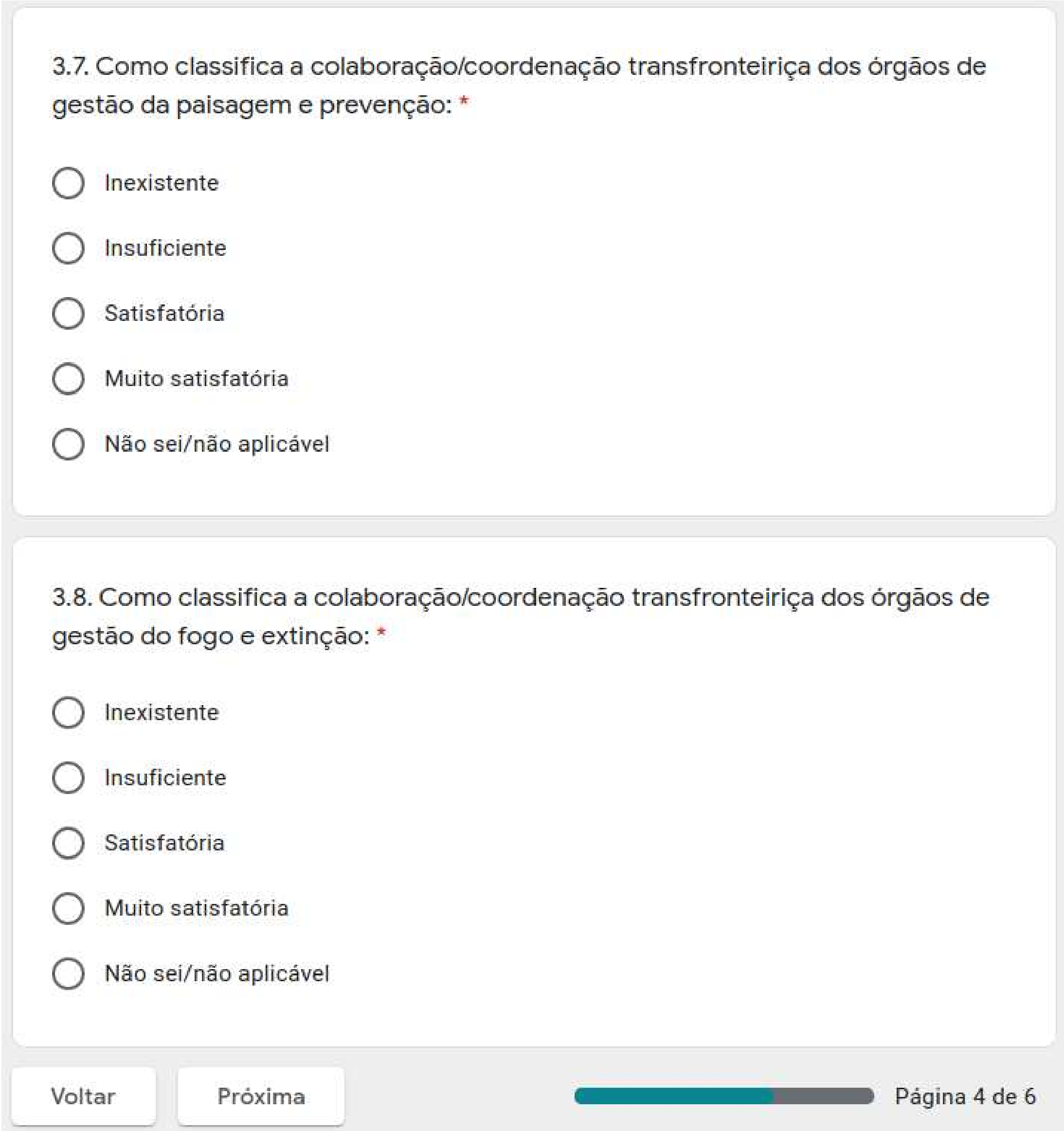
Responda apenas se preencheu a alínea i) da pergunta 3.2.

	Madeira e lenha	Agricultura e pecuária	Regulação climática	Regulação hídrica	Identidade cultural	Turismo e recreação	Não sei/não aplicável
i) Outro tipo de gestão sugerido	☐	☐	☐	☐	☐	☐	☐

3.6. Como mediria o êxito de uma política de prevenção de grandes incêndios florestais? (selecione no máximo 3 opções) *

- ☐ Redução da área total queimada.
- ☐ Redução do impacto nas pessoas e bens afetados.
- ☐ Redução da severidade dos incêndios.
- ☐ Criação de novos postos de trabalho.
- ☐ Contribuição para a conservação da biodiversidade.
- ☐ Manutenção do fornecimento sustentável de serviços ecossistémicos.
- ☐ Não sei/não aplicável.

Figure A1. (continued)



3.7. Como classifica a colaboração/coordenação transfronteiriça dos órgãos de gestão da paisagem e prevenção: *

- Inexistente
- Insuficiente
- Satisfatória
- Muito satisfatória
- Não sei/não aplicável

3.8. Como classifica a colaboração/coordenação transfronteiriça dos órgãos de gestão do fogo e extinção: *

- Inexistente
- Insuficiente
- Satisfatória
- Muito satisfatória
- Não sei/não aplicável

Voltar | Próxima | Página 4 de 6

Figure A1. (continued)

4. Dados pessoais

As informações coletadas nesta pesquisa serão utilizadas exclusivamente para fins científicos, e por isso, serão tratadas de forma anónima e confidencial. Os campos nome, organização e e-mail são opcionais, e poderá preenchê-los caso queira receber posteriormente os resultados deste estudo. Em nenhum caso os dados pessoais constarão nos resultados da pesquisa, uma vez que estes serão agrupados por setores do território. *

☐ Eu autorizo que as informações sejam utilizadas para os fins estabelecidos nesta seção.

4.1. Nome/organização

Sua resposta

4.2. email

Sua resposta

Gostaria de receber os resultados do estudo?

☐ Sim

☐ Não

4.3. Idade

☐ < 20

☐ 20 - 29

☐ 30 - 39

☐ 40 - 49

☐ 50 - 59

☐ > 60

Figure A1. (continued)

4.4. Sector *

- ◯ Gestão florestal
- ◯ Produção agrícola ou pastoril
- ◯ Proteção florestal (prevenção e/ou extinção de incêndios)
- ◯ Proteção civil
- ◯ Conservação da natureza
- ◯ Investigação científica
- ◯ Governamental
- ◯ Outro: ____________

4.5. Relevância do seu perfil/setor na tomada de decisão *

- ◯ Muito alta
- ◯ Alta
- ◯ Meio
- ◯ Baixa
- ◯ Muito baixa
- ◯ Não aplicável

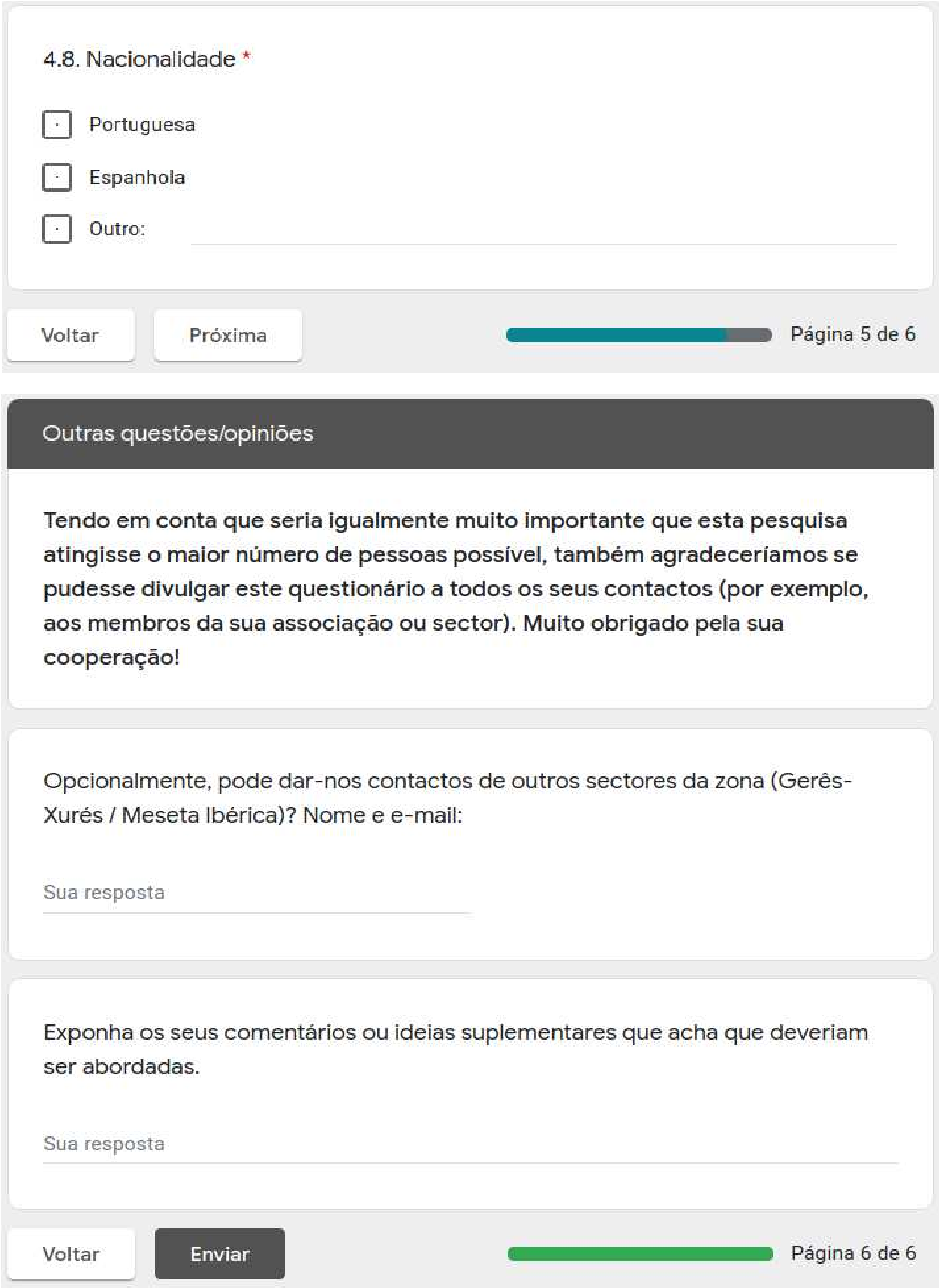
4.6. Anos de experiência na área *

Sua resposta

4.7. Área de acção *

- ◯ Gerês - Xurés
- ◯ Meseta Ibérica
- ◯ Não aplicável

Figure A1. (continued)



4.8. Nacionalidade *

- [ ] Portuguesa
- [ ] Espanhola
- [ ] Outro: ____

Voltar | Próxima | Página 5 de 6

Outras questões/opiniões

Tendo em conta que seria igualmente muito importante que esta pesquisa atingisse o maior número de pessoas possível, também agradeceríamos se pudesse divulgar este questionário a todos os seus contactos (por exemplo, aos membros da sua associação ou sector). Muito obrigado pela sua cooperação!

Opcionalmente, pode dar-nos contactos de outros sectores da zona (Gerês-Xurés / Meseta Ibérica)? Nome e e-mail:

Sua resposta

Exponha os seus comentários ou ideias suplementares que acha que deveriam ser abordadas.

Sua resposta

Voltar | Enviar | Página 6 de 6

Figure A1. (continued)