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Fire-smart management as nature-based solution to extreme wildfires in abandoned rural landscapes of Southern Europe

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Abstract

In Mediterranean regions worldwide, climate and landscape change increased the occurrence and the risk of (very) large and intense fires, which override the current firefighting capacity. Fire management policies, largely focused on fighting at the expense of prevention, have proven inadequate to address this challenge. Agricultural abandonment has shaped rural mountain areas in many parts of Southern Europe since the last century, owing to diverse socio-economic and biophysical constraints such as reduced job opportunities, poor generational renewal, low accessibility and soil productivity. The cessation of traditional livestock and agricultural practices caused by rural exodus has favoured more homogeneous and flammable landscapes —with strong side-effects on fire regime, ecosystem services and biodiversity.

In fact, the challenge for managers and policy makers is no longer simply how to reduce wildfire impacts but how to reconcile socio-economic impacts of fires with their ecological benefits. Fire-smart management would clearly enable a more balanced integration of positive (reducing species competition, diseases and pests or fire intensity, and increase fire protection in wildland-urban interfaces) and negative contributions of fire to human well-being, which would inform better decision making in fire management policy and land-use planning. In practice, fire-smart landscapes can be obtained by fuel-reduction treatments and by fuel type conversion, rather than by fuel isolation. From this perspective, proactive management should therefore focus on reshaping vegetation (fuel) configuration to foster more fire-resistant and/or fire-resilient landscapes while simultaneously ensuring the long-term supply of ecosystem services and biodiversity conservation. In contrast, rewilding has been proposed as an opportunity for biodiversity conservation in abandoned landscapes. However, rewilding is challenged by the increasing fire risk associated with more flammable landscapes, and the loss of open-habitat specialist species.

Here we present three complementary studies carried out in the frame of the FirESmart project (https://firesmartproject.wordpress.com) focusing on two contrasting land-use policy scenarios (Rewilding vs High Nature Value farmlands) based on stakeholders' perception of fire-landscape dynamics, and their potential impacts on biodiversity conservation and ecosystem services. Our studies were implemented in a transboundary protected area, the Gerês-Xurés Biosphere Reserve, where we predicted the potential impacts in terms of fire regime change, species conservation and carbon sequestration.

Our studies contribute to the increasing evidence of agricultural policies as essential tools to ensure biodiversity while reducing fire hazard, an aspect that has been frequently neglected when assessing the beneficial effects of agricultural policies. Also, our findings suggest using fire to enhance rewilding as an alternative management strategy in our study area — an issue that decision makers and managers should consider when implementing rewilding initiatives in other fire-prone regions. These studies represent the needs of local communities in these mountainous areas, which are heavily

affected by rural abandonment, fire regimes, and loss of natural resources. These rural communities try to keep alive the few and scarce agricultural activities and manage the mountain landscapes. However, the reduced investment and financial support of these isolated communities has led to the decline of these traditional fuel and habitat management tools.

1. Introduction

Wildfires are a major component of disturbance regimes worldwide (Keeley et al., 2012). Despite the increasing amount of resources invested in fire suppression, the number of extreme fire events has largely increased over the last decades in southern Europe, overriding current fire-suppression systems (San-Miguel-Ayanz et al., 2013). Agricultural abandonment has shaped rural mountain areas in many parts of the Mediterranean Europe since the last century, owing to diverse socio-economic and biophysical constraints such as reduced job opportunities, poor generational renewal, low accessibility and soil productivity (Cerqueira et al., 2010; MacDonald et al., 2000).

Society has co-evolved with fire over centuries (Pausas & Keeley, 2019). In rural areas, fire was also used as a tool for land management (e.g., clearing land for pastures Chas-Amil et al., 2015; Tedim et al., 2016), which resulted in a large number of low-intensity and small-sized fires (Chas-Amil et al., 2010). At the same time, fire has been perceived by society as a damaging hazard with only negative impacts, which reinforced fire exclusion and suppression policies. In the last decades, as a result of both agricultural abandonment and fire exclusion policy, Mediterranean landscapes have become more homogeneous and flammable (Moreira et al., 2011) and therefore more susceptible and vulnerable to forest fires.

The interactions between fire and landscape dynamics in these complex socio-ecological systems hinder how to efficiently treat landscapes in terms of spatial configuration and density of treatments (Alcasena et al., 2018; Oliveira et al., 2016; Thompson et al., 2017). In protected areas, landscape management becomes more complex because legislation regulates management, which together with land ownership constraints, complicates treatment allocation (Alcasena et al., 2018). Therefore, treatment strategies must consider multiple objectives and should involve the needs and views of stakeholders in relation to fire and landscape management. In particular, fire management strategies in these areas have been directed towards promotion of agro-pastoral activities, total or partial removal of the fuel in strategic areas, and use of prescribed burning.

More recently, fire-smart management (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) has been proposed as an alternative including fire as a socio-ecological process while balancing the benefits and drawbacks of fire to human well-being (Fernandes, 2013).

On the contrary, land abandonment in rural landscapes is one of the most important drivers of regional land-use change (Estoque et al., 2019), and has been suggested as an opportunity for biodiversity conservation and the reinstatement of natural ecological processes (Queiroz et al., 2014). However, rewilding holds some constraints that may limit its successful implementation. The inherent homogenization of rewilded landscapes leads to loss and fragmentation of open habitats, mainly due to shrub encroachment and forest expansion (Moreira et al., 2011). Studies also indicated that the gradual cessation of traditional farming areas, many of which known to support “High Nature Value farmlands” (hereafter HNVf), is a major cause of local biodiversity losses, accelerating population declines of species adapted to wet grasslands, pastures and other extensive agricultural areas (Franks et al., 2018; Ribeiro et al., 2014). The intricate links between land abandonment and fire regimes complexify the selection of appropriate alternative scenarios, and subsequently decision-making in fire management and planning (McLauchlan et al., 2020).

In this new era of megafires, the question is how landscape management could integrate social and ecological perspectives to solve the growing problem of forest fires. Possibly, the most effective way to integrate both dimensions of this societal challenge in fire-prone regions is mainstreaming fire-smart management as Nature-based Solution (hereafter NbS).

1.1. Aims

These studies have sought to address several important issues in landscape and fire regime management, nature conservation, and the inclusion of local stakeholders in the understanding of these complex processes.

Firstly, we analysed stakeholders' perceptions about wildfire-landscape interactions in abandoned rural landscapes of Southern Europe, and how fire and the territory should be managed to reduce wildfire hazard and ensure the long-term supply of ecosystem services. To do so, we have used a structured online questionnaire that was sent to stakeholders. We also analysed the differences in the stakeholders' perceptions among sectors and we also explore to what extent fire management strategies can be considered Nature-based Solutions using the IUCN standard.

The second study aimed to identify 'win-win' situations to reduce the impact of wildfires and maximize the provision of carbon storage and sequestration and biodiversity conservation in fire-prone regions affected by rural abandonment. We assessed the potential trade-offs between wildfire mitigation (measured through total burned and suppressed area), climate regulation ecosystem services (i.e., carbon storage and sequestration) and biodiversity conservation under fire-smart management scenarios.

Lastly, we assessed the impacts of alternative landscape trajectories and fire suppression management strategies on future fire regimes and on biodiversity conservation. We focused on changes in burned and suppressed areas and habitat availability for 211 vertebrate species. We aimed to answer the following questions: 1) How would different land-use and fire suppression management scenarios contribute to future fire mitigation (i.e. fewer areas burned associated with higher suppression efficiency)?, 2) How would those scenarios affect biodiversity?; 3) Which is the best management scenario for promoting fire mitigation and biodiversity conservation?; and 4) With agricultural policies failing to cope with rural abandonment, could a rewilding trajectory integrated with fire suppression policies contribute to enhance biodiversity conservation?

2. Methodology

2.1. Study area

These studies were conducted in the Transboundary Biosphere Reserve Gerês-Xurés (ca. 276,000 ha, of which 71% in Portugal and the remaining 29% in Spain), a representative mountain landscape of NW Iberian Peninsula. The region is located at the transition between the Mediterranean and Eurosiberian (Temperate) biogeographic zones, close to the Atlantic coast. The study area includes the entire reserve, encompassing three EU Natura 2000 sites besides two nationally designated protected areas, the Peneda-Gerês National Park in Portugal and the Baixa Limia - Serra do Xurés Natural Park in Spain. Although our study is conducted in the entire Biosphere Reserve, we intend to discern the management impacts both within and outside protected areas, given the differences between both areas in terms of socio-economic values and protection measures, which would influence how the different management strategies could be implemented.

2.2. Local stakeholders' perception and scenarios design

The questionnaire was conducted based on an online questionnaire structured in four sections related to: 1) fire; 2) landscape; 3) and potential impacts of fire management strategies on fire regime, and ecosystem services; (see details in Lecina et al. *under review*).

2.3. Modelling framework

We used a spatially explicit process-based model (REMAINS) that integrates the main factors driving fire-landscape dynamics (Pais et al., 2020). The model allows investigating how the spatiotemporal interactions between fire-vegetation dynamics, fire management and land-use changes affect fire regime at short- and medium-timescales. The REMAINS model reproduces fire-landscape dynamics according to pre-designed scenario storylines (Pais et al., 2020). In particular, the model simulates wildfires (including fire ignition, spread, burning and extinction), vegetation dynamics (natural succession), land-use changes (agriculture abandonment or intensification) and forest management.

We combined fire-landscape model simulations with species distribution models to identify the best strategies for wildfires prevention and bird conservation (between 1990 to 2050). This model was calibrated using historical fire statistics and landscape change analysis based on remote sensing information. We run fire-simulated fire-landscape dynamics under scenarios with different land-use and fire management policies, based on four storylines (Figure 1) (Pais et al., 2020).

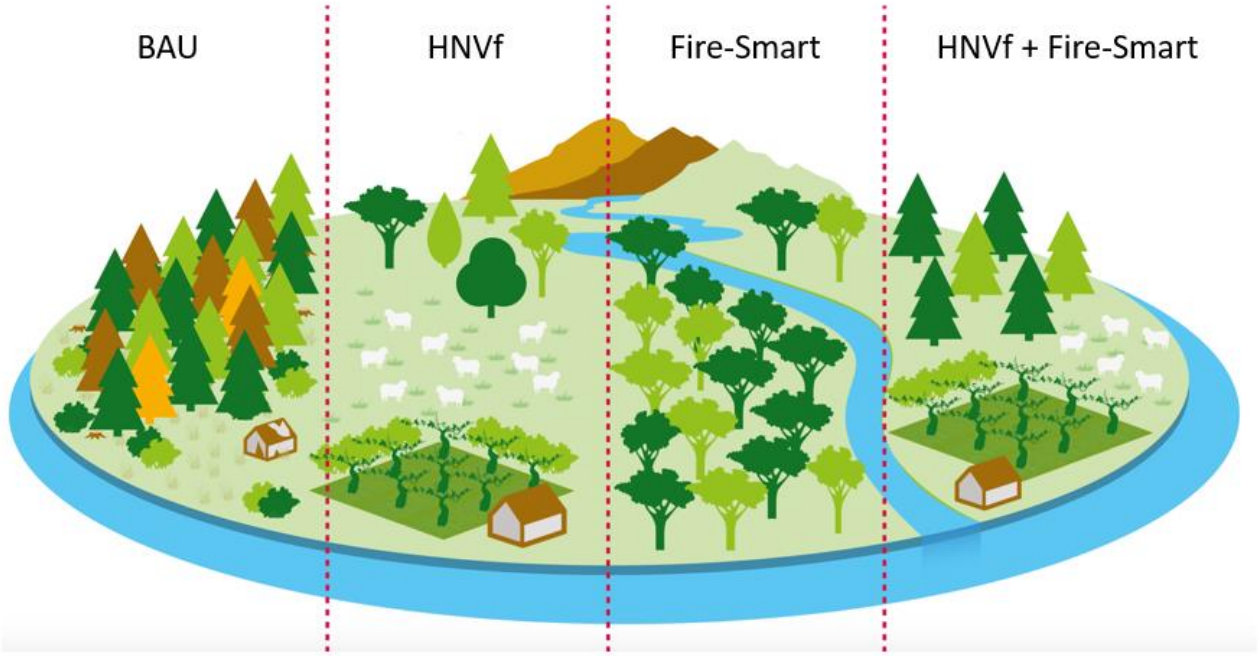

Figure 1 - Storylines: Business-as-usual scenario (BAU) describes the current trend of land abandonment; High Nature Value Farmland (HNVf) represents a policy promoting traditional agricultural activities. Fire-smart scenarios aims to create landscapes more resistant to wildfires. HNVf plus Fire-smart combines these two policies (see details in Pais et al., 2020) (extracted fr om Hernández, 2021).

To predict biodiversity distribution, we used species data from atlases and fire-landscape model simulations under the 4 most extreme scenarios. We applied an ensemble modelling approach from different modelling techniques for these species, to account for the uncertainty related to the modelling technique (see Pais et al., 2020). We conducted a biophysical assessment of the climate regulation ecosystem service (hereafter CRES) based on the carbon sequestration ecosystem function, by applying the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) model. We evaluated the impact of fire and land-use management scenarios on this ecosystem service over a period of 63 years (1987–2050) (see Campos et al., 2021).

3. Results and conclusions

The first step showed stakeholders' perceptions about fire, its impacts on the landscape, and the fire management opportunities. Overall, there is a 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 perceived 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 situation that they expect to continue in the future in the absence of management. Regarding fuel management, all strategies except using chemical methods were accepted by the stakeholders who perceive more positive than negative effects of fire management on forest ecosystem services. In particular, promoting agricultural and livestock uses, modifying forest species composition to increase fire resistance, and introducing large herbivores have potential to become effective Nature-based Solutions in the regions. 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. This study is a first-step analysis for the co-design and co-implementation of these fire management strategies as NbS, which will guarantee its successful application in solving the societal challenges and contributing to the sustainable development of the areas.

Our findings also found the benefits of integrating proactive land-use policies and fire-smart management strategies at the regional scale to promote sustainable solutions to the forest fires problem in abandoned mountain landscapes of Southern Europe. Overall, our results highlight that land-use policies aimed at promoting farmland areas would provide fire-suppression opportunities while simultaneously ensuring biodiversity conservation within (and around) protected areas. Our results confirm the urgent need for policies

promoting farmland areas, both in terms of future fire-suppression opportunities and biodiversity conservation. A large amount of strategically allocated cropland areas (at least 1,200 ha per year) should be gradually incorporated to the landscape along the next decades to significantly affect fire regime in the medium term. These policies would be also positive for conservation objectives since most of the species would benefit for the recovery of habitats associated with agricultural activities. In terms of long-term supply of the climate regulation ecosystem service (through carbon sequestration), our models predicted the best outcomes under large-scale fire-smart forest conversion. However, the integration of this fire-smart landscape conversion would be only acceptable for biodiversity conservation and fire prevention if embedded in landscape matrix characterized by increasing agricultural areas over the next decades.

The last study contributes to the increasing evidence of agricultural policies as essential tools to ensure biodiversity while reducing fire hazard, an aspect that has been frequently neglected when assessing the beneficial effects of agricultural policies. Also, this study suggests using fire to enhance rewilding as an alternative management strategy in our study area — an issue that decision makers and managers should consider when implementing rewilding initiatives in other fire-prone regions. Additionally, our study highlights the need for renewed political and socio-economic efforts exploring different solutions to economic incentives and/or management strategies integrating both rewilding and HNVf. In this context, our study demonstrates how an effective implementation of European agricultural policies could benefit biodiversity (through the creation of new open habitats for endangered species) while providing further fire-suppression opportunities. Our study also shows how fire suppression policies can help the implementation of rewilding initiatives in other abandoned, fire-prone mountain areas across Southern Europe (see dissemination video at https://youtu.be/x7ouTIBp__E).

4. References

Alcasena, F. J., Ager, A. A., Salis, M., Day, M. A., & Vega-Garcia, C. (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

Campos, J. C., Bernhardt, J., Aquilué, N., Brotons, L., Domínguez, J., Lomba, Â., Marcos, B., Martínez-Freiría, F., Moreira, F., Pais, S., Honrado, J. P., & Regos, A. (2021). 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

Cerqueira, Y., Araújo, C., Vicente, J., Pereira, H. M., & Honrado, J. (2010). Ecological and Cultural Consequences of Agricultural Abandonment in the Peneda-Gerês National Park (Portugal). In Natural Heritage from East to West (pp. 175–183). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-01577-9_22

Chas-Amil, M. L., Prestemon, J. P., McClean, C. J., & Touza, J. (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., Touza, J., & Prestemon, J. P. (2010). Spatial distribution of human-caused forest fires in Galicia (NW Spain). In G. Perona & C. A. Brebbia (Eds.), Modelling, Monitoring and Management of Forest Fires II (pp. 247–258).

Estoque, R. C., Gomi, K., Togawa, T., Ooba, M., Hijioka, Y., Akiyama, C. M., Nakamura, S., Yoshioka, A., & Kuroda, K. (2019). Scenario-based land abandonment projections: Method, application and implications. Science of The Total Environment, 692, 903–916. https://doi.org/10.1016/j.scitotenv.2019.07.204

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

Franks, S. E., Roodbergen, M., Teunissen, W., Carrington Cotton, A., & Pearce-Higgins, J. W. (2018). Evaluating the effectiveness of conservation measures for European grassland-breeding waders. Ecology and Evolution, 8(21), 10555–10568. https://doi.org/10.1002/ece3.4532

Hernández, L. y cols. (2021). Paisagens corta-fogos. Proposta da ANP|WWF e WWF Espanha para um território ibérico adaptado aos incêndios. www.natureza-portugal.org

Hirsch, K., Kafka, V., Tymstra, C., McAlpine, R., Hawkes, B., Stegehuis, H., Quintilio, S., Gauthier, S., & Peck, K. (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

Keeley, J., Bond, W., Bradstock, R., Pausas, J., & Rundel, P. (2012). Fire in mediterranean ecosystems: ecology, evolution and management.

MacDonald, D., Crabtree, J. ., Wiesinger, G., Dax, T., Stamou, N., Fleury, P., Gutierrez Lazpita, J., & Gibon, A. (2000). Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response. Journal of Environmental Management, 59(1), 47–69. https://doi.org/10.1006/jema.1999.0335

McLauchlan, K. K., Higuera, P. E., Miesel, J., Rogers, B. M., Schweitzer, J., Shuman, J. K., Tepley, A. J., Varner, J. M., Veblen, T. T., Adalsteinsson, S. A., Balch, J. K., Baker, P., Batllori, E., Bigio, E., Brando, P., Cattau, M., Chipman, M. L., Coen, J., Crandall, R., … Watts, A. C. (2020). Fire as a fundamental ecological process: Research advances and frontiers. Journal of Ecology, 108(5), 2047–2069. https://doi.org/10.1111/1365-2745.13403

Moreira, F., Viedma, O., Arianoutsou, M., Curt, T., Koutsias, N., Rigolot, E., Barbati, A., Corona, P., Vaz, P., Xanthopoulos, G., Mouillot, F., & Bilgili, E. (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

Oliveira, T. M., Barros, A. M. G., Ager, A. A., & Fernandes, P. M. (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., Aquilué, N., Campos, J., Sil, Â., Marcos, B., Martínez-Freiría, F., Domínguez, J., Brotons, L., Honrado, J. P., & Regos, A. (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

Pausas, J. G., & Keeley, J. E. (2019). Wildfires as an ecosystem service. Frontiers in Ecology and the Environment, 17(5), 289–295. https://doi.org/10.1002/fee.2044

Queiroz, C., Beilin, R., Folke, C., & Lindborg, R. (2014). Farmland abandonment: threat or opportunity for biodiversity conservation? A global review. Frontiers in Ecology and the Environment, 12(5), 288–296. https://doi.org/10.1890/120348

Ribeiro, P. F., Santos, J. L., Bugalho, M. N., Santana, J., Reino, L., Beja, P., & Moreira, F. (2014). Modelling farming system dynamics in High Nature Value Farmland under policy change. Agriculture, Ecosystems and Environment, 183, 138–144. https://doi.org/10.1016/j.agee.2013.11.002

San-Miguel-Ayanz, J., Moreno, J. M., & Camia, A. (2013). Analysis of large fires in European Mediterranean landscapes: Lessons learned and perspectives. Forest Ecology and Management, 294, 11–22. https://doi.org/10.1016/j.foreco.2012.10.050

Tedim, F., Leone, V., & Xanthopoulos, G. (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

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