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Systematizing experts' risk perception on rural fires resulting from traditional burnings in Portugal: A Mental Model approach

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Abstract

Fire is a traditional method used for the elimination of residual materials from agricultural and forestry activities, but its improper and negligent use increases the risk to cause significant social, economic, and environmental impacts. Translating the nature and magnitude of the risk, a mental model approach has been used for a deeper understanding of what can be done to reduce future socioeconomic and environmental impacts. Considering the rural fire risk context, in this study we applied the mental model approach to (1) systematize the aggregated knowledge of experts on rural fire risks, focusing on the burning problem, and (2) explore the different perspectives of experts on the subject. Experts are actors with in-depth involvement and experience in fire and forest management in Portugal, including actors from industry, academics, third sector, and public entities. Semi-structured interviews that included real-time interactions with the proposed mental model on the MURAL platform were remotely conducted with twenty-eight experts. The contributions were periodically validated by the research team and included in the reference mental model to translate the aggregated knowledge of the expert community. The data collected was transcribed, coded, and analyzed following a thematic analysis approach with NVivo software support. After nine iterations, the expert's mental model was concluded encompassing the burning motivators, alternative solutions, associated risks before and during the burning, underlying causes, natural elements and factors, and impacts.

Overall, the study provides an in-depth and holistic understanding of rural fire risks, focusing on burning, which is essential for identifying incorrect beliefs and existing risk factors that are often neglected. The participatory and dynamic process of actors' knowledge systematization on burning risks through a mental model allowed the identification of divergent perspectives between expert groups, especially concerning the effectiveness of the current legislation on the use of fire, indicating the need to improve the dialogue between experts. Moreover, the study shows how risk communication campaigns do not replace technical monitoring closer to the population, given that the diversity of people inhabiting fire-prone areas in peri-urban landscapes (that holds widely varying experiences, beliefs, attitudes, and values relating to fire) can influence people's understanding and interpretation of risk messages. Thus, it is recognized the importance and need of sensitization and communication actions to disseminate adequate and safer burning practices and available alternatives. Still, it indicates that alternative solutions of burning (such as on-site pellet processing, local micro-plants for heat production, community initiatives of composting, as well as crushing and distribution of crushed material to be incorporated into the soil) may be achieved with strong local and sectoral involvement. Finally, this research provides a baseline to help decision-makers and stakeholders identify the relevant associated risks before and during the burning practice, which can support the design of effective risk communications strategies and mitigate social and environmental impacts in the future.

1. Introduction

Ignitions from human activity are responsible for 98% of all fire incidents in Portugal (SGIF, 2020). The improper use of fire corresponds to more than half of the 41% of fires attributed to negligent causes in 2020, according to presented data by the Institute for the Conservation of Nature and the Forest (ICNF), which increase the risk to cause significant social, economic, and environmental impacts. However, fire is a traditional method used for the elimination of residual materials from agricultural and forestry activities, it is also commonly used as a cleaning method to eliminate of excess biomass in the control of invasive species, and its misuse causes the

positions it as the main cause among the rural fires that occurred in Portugal (Nunes et al. 2021; Meira Castro et al. 2020; Pereira et al. 2013)

Most fires start in the proximity of agricultural areas and at the interface of urban spaces (Pacheco et al. 2020). The proximity of forest and agricultural spaces to the urban context and the accumulation of variables linked to climate change, namely, the increase in average temperatures, the reduction of precipitation and relative humidity of the air, justify the recurrence of rural fires (Nunes et al. 2021). In addition, high temperature and drought, acting as important drivers for the burned area in Portugal (Turco et al. 2019), the risk of rural fires can be aggravated due to the accumulation of fuel load. Despite efforts to improve fire management, as Decree-Law 14/2019 that make burning prior communication and authorization mandatory, the risk of rural fires stems in part from the absence of effective management policies aimed at rural areas (Coelho et al., 2020). Furthermore, some studies point out that implementing risk-based long-term planning would improve fire management efforts (Turco et al., 2019). But governmental efforts to reduce wildfire risk are not enough on their own, and it is recommended that risk mitigation strategies be a joint effort between public agencies and private landowners (Doerr et al. 2013). A current poor translation of risk information materials into mitigation actions may be attributed to the diversity of people inhabiting fire-prone areas in peri-urban landscapes. The widely varying experiences, beliefs, attitudes, and values relate to fire can influence people's understanding and interpretation of risk messages and constrain their actions (Eriksen and Prior 2011).

Resorting to the literature on risk communication and wildfire (Steelman and McCaffrey 2013), we came across studies that address "mental models" approach. That approach has been used to translate the nature and magnitude of the risk, allowing for a deeper understanding of what can be done (Morgan et al. 2002) to mitigate social and environmental impacts in the future.

The mental model's concept was originally defined as "small-scale models" of reality that [the mind] uses to anticipate events, to reason, and to underlie explanation' (Craik, 1943), being essential to choose safe alternatives in critical situations, highlighting its relevance in risk communication. The application of mental models in studies of communication and risk perception aims to identify specific information needs (e.g., gaps in knowledge, misunderstandings, questions, concerns about terminologies and beliefs of the population) for decision by contrasting the mental models of specialists and lay people concerning a specific risk (Morgan et al., 2002). Therefore, it is a method that continues to receive attention in different contexts and fields of study, for example: to capture and compare the mental models of those conducting restoration activities to inform potential policy changes (Walpole et al. 2020), to investigate perceptions of risk and mitigation of employees (Stege et al., 2019), to compare perspectives of government agencies, academic experts, and suppliers on providing risk information (Aliperti et al., 2020).

According to Zaksek and Arvai (2004), risk management information and topics vary considerably between experts, actors from different stakeholder groups, and laypeople. In addition, groups may have different windows of knowledge about a particular risk, leading to an agreement between groups and management decisions that are not aligned with the most current scientific knowledge. The fundamental notions about risk, its characteristics, impacts, and forms of control are always necessary, so the level of understanding of the target group adjusts with the new information (Breakwell, 2001).

As such, in this study, we use a mental model approach to (1) systematize the aggregated knowledge of experts on rural fire risks, focusing on the burning problem, and (2) explore the different perspectives of experts on the subject. Based on scientific data about rural fire risks and the aggregated knowledge of the expert community, a mental model was built that encompasses the motivators, alternative solutions, associated risks, underlying causes, natural elements and factors, and impacts about burning. An in-depth and holistic understanding of rural fire risks, focusing on burning, is essential for maintaining cohesion between actors and building effective risk communications strategies to mitigate social and environmental impacts in the future.

2. Method

Based on the literature review, the methodological premises for the development of the study were established; the first one was the mental model's elaboration, commonly represented by an influence diagram. The research design involved the development of the data collection instrument (semi-structured interview scripts), the

systematization of data collection with different stakeholders (mental model development in a digital visual collaboration platform, called MURAL) on the risk of rural fires, focusing on the burning problem. Interviews were conducted virtually (by Zoom), and each interview took, on average, 1h30min. To gather a richer understanding of the expert's perspective, this study involved a comprehensive sample, that included experts from academia (7), industry (5), public entities (9), and third sector (7), accounting for 28 interviews, as shown in table 1.

Table 1 - Sample description

Experts	Number of participants (% sample)	Role
Industry	5 experts (18%)	Executive Director, Head of Department, Directors, and Manager
Academy	7 experts (25%)	Ph.D. and Associate Professors
Third sector	7 experts (25%)	Executive Director, Chairman of the Board, Engineers and Technical consultant
Public entity	9 experts (32%)	Cavalry Colonel, Commanders, Operations Deputy, Engineers, Landscape architect
	N = 28 experts	

Between the entities, we had representants from National Military Security Force, Volunteer Firefighters, National Emergency and Civil Protection Authority, National Guard, Agency for the Integrated Management of Rural Fires; National Institute for the Management and Conservation of Nature and Forests, forestry companies, electricity, and natural gas transport industries, multinationals that operate in telecommunications and other segments, associations, universities.

Following ethical standards, the interviewed participants consented to record the interviews for further analysis, accounting for approximately 39 hours of recorded data.

The experts' contributions were periodically validated by the research team and incremented in the reference mental model to translate the aggregated knowledge of the expert community. The data collected were transcribed, coded, and analyzed following a thematic analysis approach with NVivo software support.

3. Findings

Given the focus of the mental model on the practice of burning and in order to explore the risks, associated variables, and mitigation modes in-depth, we set three periods (before, during, and after) to delimit the burning process from start to finish. After nine interactions of contributions validation, the expert's mental model was concluded. In total, 170 changes were counted in the mental model (including node description changes; adding, relocation, and removing nodes; adding, relocation, and removing edges). Between changes made to the mental model, 50% were made by actors from public entities, 18% by actors from academia, 23% by actors from the third sector, and 9% by actors from the industry, as shown in table 2.

	Before burning		**During burning**		**After burning**		**Total**	
Public entity	*50*	*59%*	*23*	*27%*	*12*	*14%*	*85*	*50%*
Academy	*19*	*61%*	*7*	*23%*	*5*	*16%*	*31*	*18%*
Third sector	*24*	*62%*	*10*	*26%*	*5*	*13%*	*39*	*23%*
Industry	*13*	*87%*	*2*	*13%*	*0*	*0%*	*15*	*9%*
Total	**106**	*62%*	**42**	*25%*	**22**	*13%*	**170**	***100%***

Table 2 - Changes made in the mental model by experts' group

The expert's mental model encompasses eight main blocks (Figure 1), such as motivators to burning, alternative solutions, associated risks before and during the burning practice, underlying causes and natural elements that can increase the burning risk, and potential impacts.

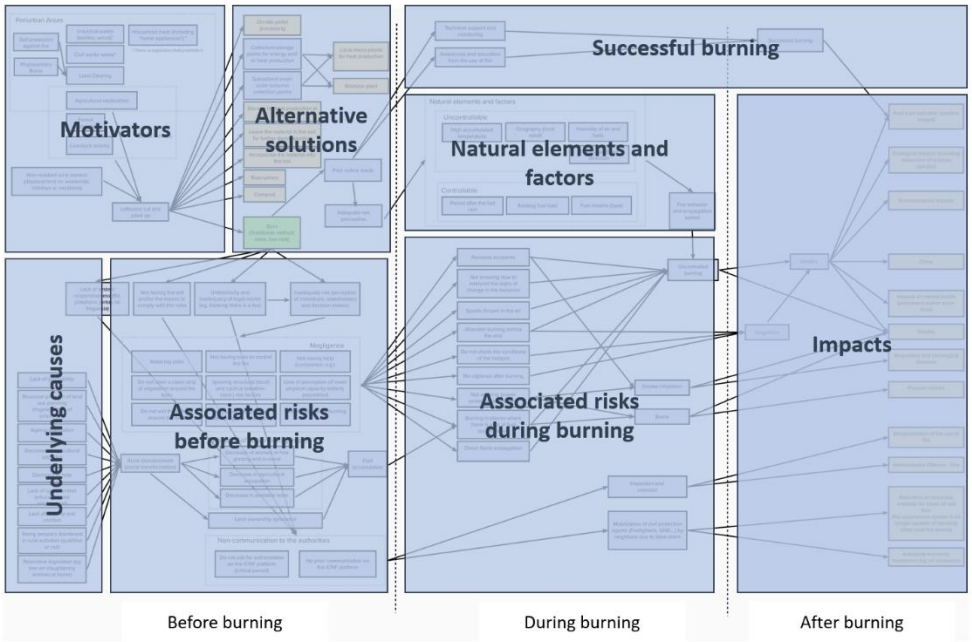

Figure 1- Expert mental model in main blocks

Before burning, the mental model shows burning motivators in peri-urban and rural areas, such as land clearing to self-protection against fire or phytosanitary burns, agricultural and forest exploration, etc.; in addition to considering the non-resident rural owners (displacement on weekends, holidays, or vacations).

Associated risks before burning block listed several risk factors and aspects that precede the practice of burning that often lead to neglect action, such as inadequate risk perception of individuals (e.g., not having a companion, ignoring structural (local) and cyclical (weather-cond.) risk factors, etc.), stakeholders, and decision-makers; unfamiliarity and inadequacy of legal norms (e.g., thinking there is a fee regarding the request for authorization to conduct a burning); lack of system responsiveness from Voluntary Fire Service, platform, Municipal Councils; or simply not having the will and/or the means to comply with the rules, leading to no prior burning communication to the authorities, thus not complying with the Portuguese Decree-Law 14/2019. Tied to this, underlying causes block describe rural abandonment causes represents indirect factors that contribute to increasing rural fire risks (e.g., lack of profitability, aging population, decrease in agricultural activities, structural problem of land use planning (fragmentation of properties), etc.), because of the absence of active management and fuel accumulation.

In contrast, alternative solutions include crushing, on-site pellet processing, leaving the material in the soil for further decomposition or incorporation to improve the structure and quality of the soil, collection/storage to use for biomass, composting, energy production, at small or large scale.

During the burning,natural elements and factors block include controllable (e.g., existing fuel load and fuel models) and uncontrollable (e.g., the humidity of air and fuels, orography, wind speed, and direction) elements that can potentially impact fire behavior and propagation speed. Associated risk block encompasses risk factors such as, not knowing how to interpret the signs of change in fire behavior, abandoning burning before the end, not wearing proper protective equipment, sparks thrown in the air, and other risk factors that can cause an uncontrolled burning or their reignition.

After burning, the mental model included twenty variables of impact, beyond the social, environmental, and economic impacts, we can mention for instance the fuel load reduction, which represents a positive impact and the reduction of resources available if there is a mobilization to false alarm of fires, which could be an avoidable investment. Lastly, successful burning block highlight actions to mitigate the risk, such as technical support and monitoring, awareness, and education from the use of fire.

4. Implications and conclusion

The findings indicate three preliminary theoretical and practical implications. First, there is a need to improve the dialogue between experts, which corroborates other research in which the mental model's approach was applied (Aliperti et al., 2020). This dialogue should focus on the perception of the administrations and decision-makers risk in the practice of burning and its relationship with the effectiveness of the current legislation on the use of fire, as some specialists have the perception of the imposition of punitive law, of repression, which leads to marginality and the illegal practice of burning. Still, many actors see the beneficial ecological role of fire, especially about reducing accumulated fuel and consequent mitigation of large fires, while other actors simply fail to identify any positive impact in this issue.

Second, alternative solutions of burning (such as on-site pellet processing, local micro-plants for heat production, community initiatives of composting, as well as crushing and distribution of crushed material to be incorporated into the soil) may be achieved with strong local and sectoral involvement. Experts agree that biomass plants are viable in some regions, where there is a market logic, the volume of material, and the plants are close for supply, making the market economically sustainable. However, this does not happen in regions where the land is fragmented, as there is no supply of material in the necessary volume, and in some cases the plants are far away, not compensating for the cost of transport, as it is a material of low value. Therefore, micro-biomass plants are identified as a relevant solution to reduce the risk of burning. Still, on this topic, specialists also state that the incentive to disseminate the use of biomass would potentially originate from public policies (e.g., percentage of energy sources must be renewable, and another percentage must contribute to the active management of fuels, in the latter case the use of biomass for home heating), what does not exempt the local and sectoral actors' involvement.

Finally, understanding that risk communication campaigns do not replace technical monitoring closer to the population. Experts believe closer technical monitoring is the main factor to contribute to rural fires risk mitigation, but given the limited operational capacity in relation to demand, they recognize the importance and need of sensitization and communication actions to disseminate adequate and safer burning practices and available alternatives.

Most effective communication practices are associated with flexible fire management and interactive communication (before and during the event), that strives to address local contextual concerns, explain actions, and provide honest, timely, accurate, and reliable information while leveraging local relationships (Steelman and McCaffrey 2013). As such, by understanding relevant actors' perception about traditional burnings, a mental model approach can support an effective risk communication strategy.

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