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COMMENTARY
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Special Section:
Fire in the Earth System

Living With Fire and the Need for Diversity

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Abstract The 2018–2021 wildfire seasons were a glimpse of the future: deadly damaging fires in Mediterranean regions and high fire activity outside the typical fire season, also in temperate and boreal areas. This challenge cannot be solved with the traditional mono-disciplinary approach of fire suppression. There is a critical need to change fire management from fire resistance to landscape resilience: Living with fire. Climate change thereby creates an urgency for understanding the integrated drivers of fire impacts and risks, and for designing creative and effective risk reduction, management and communication strategies. We argue that achieving this integrated fire management requires inter- and transdisciplinary research based on four axes of diversity: combining cross-geography, cross-risk, and cross-sector approaches while embracing social diversity. This requires a new way of training our future experts, a broader way of defining scientific excellence, and stimulation of opportunities for people from various disciplines and sectors to meet and learn.

Plain Language Summary Because fire in the landscape is often seen as bad, management of fires in the landscape tends to be focused on putting all fires out. But fire belongs in nature and fire services around the world increasingly face the limits of firefighting. Some fires are now becoming so extreme that they cannot be controlled anymore. The way out of this challenge is to accept fire in the landscape, and work with it instead of against it. Here we argue that to live with fire, diversity is essential in four ways: to better connect knowledge and people in different countries, working on different risks, and working in science and practice, and to do this with more diverse people. We conclude by giving suggestions how to achieve this, including a new way of training our future experts.

Key Points:

- Integrated fire management is needed to solve current fire challenges
- This requires a cross-geography, cross-risk and cross-sector approach embracing social diversity
- We must train the next generation of inter- and transdisciplinary integrated fire management teams based on these four axes of diversity

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1. Introduction

The world has tried to fight landscape fire for decades, and while it is widely known that fire prevention and landscape management can be done for a fraction of the costs of fire suppression (Snider et al., 2006), the standard mode is to continue resisting fire. Yet the world is changing. Climate change is increasing the frequency and intensity of droughts, strong winds and high temperatures (IPCC, 2021), and regional area burned (Williams et al., 2019). European fire regimes are moving northwards from traditionally fire-prone countries to temperate countries and new areas of the boreal (San-Miguel-Ayanz et al., 2019). Fires are now so large and damaging that even people used to living with fire are not prepared to face them, or survive (Portugal 2017; Greece 2018/21, Australia 2019/20, USA 2020/21). Extreme and unpredictable firestorms add to the challenge of controlling fires worldwide (Castellnou et al., 2019). These changes exist in a context of decades-long fire suppression and land use change that increased fuel loads, followed by migration of urban people into the wildland-urban interface (Iglesias et al., 2021; Tedim et al., 2015), and an annual influx of tourists into fire-prone regions. In temperate regions like in Northwest Europe, fire as a new risk exists amidst low awareness and preparedness of citizens, governments and emergency services, and high population densities, while people enjoy living and recreating in green areas that are of considerable socialeconomic value (Public Health England, 2020). Across the globe there is a critical need to be prepared to live with fires unlike those we know from the past.

Living with fire requires acceptance of fire's natural role in the landscape (Fernandes et al., 2013), to move from fire suppression to prevention to adaptation to fire. A prime example of this can be found amongst Indigenous peoples around the world, who have lived with fire for thousands of years. They used good fire for their own benefit and to reduce the potential for destructive ones, until fire use was banned by colonial settlers who believed fire was bad (Christianson, 2014). Now western society is slowly turning to these age old approaches to learn to live with fire (Mason et al., 2012). To do so, landscape fires should be managed more holistically to make communities and landscapes more fire resilient (Smith et al., 2016; Tedim et al., 2021; WFEC, 2014). This holistic approach finds a basis in the field of pyrogegraphy (Bowman et al., 2013) and integrated fire management

Figure 1. Living with fire requires inter- and transdisciplinary research approached from four axes of diversity: cross-geography, cross-risk, cross-sector, and social diversity.

(European Commission, 2018; FAO, 2006; Rego et al., 2021), that maximizes the benefits of fire and includes social, economic, cultural and ecological values in each step of the management cycle (prevention, preparedness, response, mitigation and recuperation). This requires science-informed decisionmaking that can only be achieved with the cooperation and collaboration of multidisciplinary teams that include the range of actors involved. The current challenges, particularly in Europe, lie in the quantification of the risks and the reduction and communication of these risks by all actors involved, prior, during and after fires, examining fire danger and community vulnerability, fire use, fire behavior and impacts, through to fire resilient governance and preparedness. In a global context, we argue that to achieve integrated fire management, embracing diversity is key: through inter- and transdisciplinary research that combines cross-geography, cross-risk, and cross-sector approaches and embraces social diversity (Figure 1).

2. Four Axes of Diversity in Integrated Fire Management

2.1. Cross-Geography: Exchange Between Communities and Countries

Fire-prone countries have knowledge and expertise of fire processes, which is much needed in temperate regions and developing countries. Moore (2019) indicated the strong need in developing countries for basic data on fire occurrence, size and cause, prediction of fire danger and behavior, and insights into social and environmental fire impacts. Interestingly, these needs are remarkably similar to those in developed countries that are non-traditionally fire-prone, like in temperate Europe. Yet unlike in these emerging fire regions in developed countries, many local communities in developing countries have lived with fire for centuries, and tapping into this knowledge may help both developing and developed countries. Meanwhile, there are examples of strong landscape design, prevention and participatory approaches in temperate countries, which can likewise empower traditionally fire-prone

regions. The global community has valuable knowledge and skills to share, such as strong science-based guidelines for safe design of homes and their immediate surroundings (www.firewise.org), simple tools to predict fire danger (Wang et al., 2017), and transdisciplinary approaches to better involve stakeholders in scientific research (Mauser et al., 2013). There is a need to foster exchange between communities and countries by establishing an inter- and transdisciplinary fire science base using global fire expertise. Within fire-prone regions where a fire science base already exists, international exchange should focus on designing resilient landscapes and communities at various scales. Together, this approach will bring cohesion to landscape fire management and research through its integrated, interdisciplinary and overarching approaches, connecting countries with diverse climates, landscapes, governance and emergency management systems and cultures.

2.2. Cross-Risk: Bridging Water and Fire

Water and fire are opposites, yet fire and flood management have many similarities, and can also interact. Fire and floods are both spatial and can be severe, and their location and timing can be predicted to some degree (e.g., slow floods and fire danger) but not entirely (e.g., the exact locations and timing of flash floods and fire ignitions). Despite these similarities, prevention of flood impacts is much more developed and invested in than prevention of fire impacts. A country like the Netherlands (where ~60% of land is subject to coastal and river flooding and 25% is below sea level) does not only respond to floods by pumping buildings dry. Rather, it manages flood risks by defending areas that need to be protected while allowing flooding where it is least harmful, using careful landscape planning designed with stakeholders and communities (Rijke et al., 2012). Yet while prevention of flood impacts is so key in water management, the approach to fires is often not prevention of impacts but rather fire-fighting. Countries spend millions to billions of dollars on fire suppression (Hope et al., 2016; NIFC, 2021) with total post-fire recovery costs largely exceeding that (Quiggin, 2020; San-Miguel-Ayanz et al., 2018). Meanwhile, funding for fire prevention, mitigation and preparedness and fire research is lagging behind (Boustras et al., 2017; Tymstra et al., 2020). In traditionally fire-prone countries, prescribed burning targets are often not met, and other strategic fuel management is not consistently implemented because of a multitude of reasons including cost, social acceptance, lack of capacity, and suppression activities being prioritized over fuel management (Belavenutti et al., 2021; Marino et al., 2014). In emerging fire countries, risk awareness is low and landscape fire risk is often not widely taken into account in the management and design of green space, nature and forest areas, nor in the design of houses and gardens. Yet reducing fire risk is not technically complicated, it is based on preventing vegetation –"fuels"- being connected in horizontal and/or vertical directions, removing flammable materials close to homes and preventing embers from entering open windows and vents. Despite this the recent high-profile fires illustrate the global challenge to manage landscape and home ignition zone fuels at the scale required to safely reduce vulnerability of communities and valuable resources.

There is great opportunity to connect water and fire by adopting landscape design and flood prevention approaches and adapting them to fire. The Dutch have long resisted water by building dykes, but have realized that fighting water in a changing climate with sea level rise has a limit, shifting water management to give more Room for the River (Rijke et al., 2012). This major change of thinking is also needed in fire management. To move from fire resistance to landscape and community resilience requires accepting fire as a natural disturbance, and creating landscapes that can naturally cope with changing fire regimes. There is a need to build upon expertise in water management, including the Dutch Room for the River approach, to design a Living with Fire approach that makes impact prevention enticing, and transition to living with fire rather than always fighting it.

2.3. Cross-Sector: Connecting Science and Practice

In addition to better connecting countries and risks, integrated fire management can also benefit from stronger connections between science and practice. Practitioners such as fire and land managers tend to experience the effects of changing fire regimes early and therefore have a deep understanding of the challenges faced, though their geographical region of expertise and networks are traditionally more local. Connecting practitioners to the global science community can expose them to the broad international overview and opportunities/tools available to address their challenges, particularly in emerging fire countries. Whilst there are excellent examples of cross-geography knowledge transfer by practitioners, there are instances where solutions are sought locally with little scientific basis for topics already systematically studied, tested and developed internationally. This can result in at best a duplication of work, and at worst gives a false sense of safety and the maintenance of potentially

dangerous situations, such as burning tactical fires along with the wind, or systematically fighting fires at the head of the fire. At the same time there are areas where science does not have the answers and where practitioners are taking active management approaches that science can learn from. By working closely with governments and emergency services the fire community therefore needs to actively integrate science and practice through participatory approaches and transdisciplinary research, adhering to Responsible Research and Innovation principles (Owen et al., 2012). Participatory approaches have been used in fire (Bilbao et al., 2019; McGee & Langer, 2019; Otero et al., 2018) but are not commonplace. Increasing transdisciplinary approaches in fire does require continued opportunities for scientists and stakeholders to interact, like in workshops (e.g., NetRiskWork (http://netriskwork.ctfc.cat/), SURE (https://sure.efi.int/)), networks (e.g., the US Fire Science Exchange Networks) or informal messaging groups (e.g., Flamework). Stronger connection of fire science and practice will not only strengthen the science base but also create a powerful common ground to adopt lessons learned to make social and economic impact.

2.4. Social Diversity

Clearly living with fire requires embracing the diversity of voices in science and practice across disciplines, risks, and geographies. As argued by Bowman and Stoof (2019), social diversity (including diversity in cultural background and gender) is essential for achieving this. Fire science is a field where women are traditionally underrepresented (Smith & Strand, 2018). Achieving gender equity is directly relevant for how fire management is approached. Emergency management, including firefighting, is highly masculine and heroic (Eriksen et al., 2016) and the visual splendor of big fire trucks and aerial firefighting is highly attractive for media and politics. Yet living with fire requires more feminine approaches, in which relationships are built between stakeholders, sectors, disciplines and communities, for mutual trust and understanding to manage fuels and prepare communities. Integrated fire management therefore requires a more diverse group of people than traditionally involved in fire. Whilst stimulating creativity and innovation (Freeman & Huang, 2014; Nielsen et al., 2017), working in such diverse teams can initially be awkward and challenging as people prefer working with those that are like themselves (McPherson et al., 2001). But it is essential to challenge this to enhance the quality of the science, to create safe working environments in which all people (regardless of gender, race, sexuality, age, religion, etc.) feel comfortable sharing their ideas, to adopt open and transparent hiring procedures (e.g., Stoof et al., 2020), and to remove any barriers to attract and retain diverse people and help them thrive. Bias, discrimination and harassment are prevalent barriers across the workfield (Marín-Spiotta et al., 2020; Riley et al., 2020) that require collective action, including actions from professional societies (Kuo, 2017; Riley et al., 2020) and consideration of harassment as scientific misconduct (Kuo, 2017; Marín-Spiotta, 2018).

3. Implications for Training Future Experts

The diverse interdisciplinary (across disciplines) and transdisciplinary (across science and practice) understanding required for integrated fire management is significantly broader than the traditional monodisciplinary training given at universities around the world. Our future experts therefore need to be trained more holistically. In addition to having an in-depth focus and specialty, we argue that these future experts need to (a) understand the social and environmental drivers and impacts of fire, and be able to (b) deal with uncertainty (knowing the unknowns of their field), (c) communicate risks, and (d) make inter- and transdisciplinary connections to integrate across disciplines, sectors and countries. This does not mean that everyone should have a purely inter- or transdisciplinary focus, but in order for mono-disciplinary experts to effectively communicate with people from other disciplines they need a basic understanding of and respect for the diverse fields involved in fire. This broad training provides mono-, inter-, and transdisciplinary experts alike with common language and knowledge that allows them to communicate with eachother and thereby reach the required integration, not necessarily at individual level but rather at team level. The cross-disciplinary training we describe here may be provided at single universities or as collaborations between universities and countries like the international doctoral training network PyroLife (https://pyrolife.lessonsonfire.eu/)

Scientific training in more than the traditional metrics of academic success (papers and funding) additionally requires a broader recognition and rewarding of scientific excellence that also considers societal impact, such as science communication and stakeholder engagement. Useful examples of evaluating these broader impacts are the Dutch Recognition and Rewards initiative (VSNU et al., 2019) and the UK Research Excellence Framework

case studies (REF2014, 2021), with good practices being promoted by the San Francisco Declaration on Research Assessment, signed by over 20,000 individuals and organizations in 148 countries (DORA, 2021).

4. Conclusions

Fire behavior is becoming globally more extreme and wildfires more prevalent in previously less-fire prone regions. The path forward should be based on integrated fire management and the value of innovation through exchange, adoption and adaptation. This requires a new generation of fire experts, acknowledging the need for diversity in the inter- and transdisciplinary research challenges integrated fire management must face. Mono-disciplinary, interdisciplinary or transdisciplinary experts must be willing and capable to make connections between disciplines at team level, consider the needs of the field and understand the diversity of potential solutions in integrated fire management. Likewise, the future wildfire community must span across geographical regions, encompassing the key disciplines and actors in fire: from academia and research institutes to small and large businesses, governments, emergency management, practitioners and communities. In a field that is still male-dominated, this community must also be characterized by a greater social diversity to help adopt a new approach to fire, moving from fire resistance to landscape resilience, and fostering community resilience. By linking "old" and "new" fire countries, this will build a science base for landscape fire risks, impacts and management in emerging fire regions, and strengthen fire management in traditionally fire-prone areas through assessment for the potential for participatory processes and landscape design.

Data Availability Statement

Not applicable.

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