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FOREST FIRE MANAGEMENT IN GLOBAL CHANGE: THE PITFALLS OF CURRENT APPROACHES AND THE CHALLENGES OF DEVELOPING ALTERNATIVE SOLUTIONS

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FOREST FIRE MANAGEMENT IN GLOBAL CHANGE: THE PITFALLS OF CURRENT APPROACHES AND THE CHALLENGES OF DEVELOPING ALTERNATIVE SOLUTIONS

Summary: As a result of global change, forest fires are becoming more destructive worldwide. Climate change is just one of the reasons behind this trend. The accumulation of fuel due to the abandonment of rural areas and limited forest management, changing people's attitudes, development of wildland urban interface (WUI) areas, inadequate fire prevention and sometimes firefighting deficiencies, are also important contributors. In the absence of a deep understanding of the dynamics of the problem, most governments resort continually reinforcing firefighting efforts by increasing firefighting personnel and resources. However, there are clear signs that this approach is not working. Fire behaviour is increasingly reaching mega-fire levels, and fire disasters, including fatalities, are also increasing in magnitude and frequency. An alternative approach to fire management is urgently needed. It should be based on a good understanding of the complexity of the forest fire problem, approach it holistically and devote more attention and financial resources to fire prevention, which should not be limited to technical solutions but should emphasise the cooperation with the local population and the development of resilient agricultural and forest landscapes and communities. The implementation challenges are manifold and will be discussed.

Keywords: *forest fire management, global change, fire prevention, resilient landscape*

INTRODUCTION

Forest fires are a natural phenomenon that plays an important role in most of the world's forest ecosystems, but they can also be a serious natural hazard that can lead to major disasters. Fire ecologists have extensively analysed their natural role, which differs significantly from forest ecosystem to forest ecosystem, while another branch of fire research has focused on their occurrence and significance as a natural disaster. Looking at the literature on the history of forest fires over time and other scientific literature on the characteristics of fires and the challenges they pose to management, it is immediately clear that the occurrence of fires changes over time. Indeed, in today's fast-changing world, there is clear evidence that forest fires are an ever-increasing problem around the world. This assertion is first discussed first, before focusing on an examination of current management approaches, their likely shortcomings and the alternative solutions available.

THE EVOLUTION OF THE FOREST FIRE PROBLEM

In recent decades, forest fires have taken up a great deal of space in the newspapers and mass media every summer, attracting the attention of the public. Reports of large, devastating fires are often accompanied by photos of burnt houses, cars and infrastructure, in addition to views of blackened forest landscapes. What is particularly worrying is that they are often accompanied by news of fatalities among citizens and firefighters. Although, as with other natural disasters, there is scepticism that the extensive and quick reporting we have nowadays is largely responsible for distorting the view of the true global trends, careful analysis supported by statistics and other evidence has shown that the forest fire problem is worsening around the globe, although the pace is not the same everywhere (Sullivan et al., 2022). The total area burnt is not necessarily increasing (Doerr & Santin, 2016, Turco et al. 2016, Jones et al., 2022, San-Miguel-Ayanz et al., 2023) but fire disasters are certainly increasing (Salguero et al. 2020, Buechi et al., 2021, Donovan et al., 2023) as a smaller number of extreme fire events cause devastation (Royé et al. 2020) and are often associated with numerous fatalities (Molina-Terrén, et al., 2019, Haynes et al., 2020, Xanthopoulos & Galloway, 2024). Citizens are worried or even angry, as they watch the news with awe, often feeling helpless, or they witness the threat first-hand in their vicinity, as evidenced by the corresponding content in the mass media and social media (Xanthopoulos, 2008). This is reflected in the urgency that politicians feel to "do something", which leads them into the so-called "firefighting trap" (Xanthopoulos et al., 2020a). Finally, there have been many cases where forest fire disasters have led to the resignation of ministers and possibly even contributed to the outcome of elections.

Another recent development of the forest fire problem has to do with the places where large fires occur. The European Mediterranean countries, as well as other regions of the world with a Mediterranean climate, such as California, parts of Australia, Chile and South Africa, used to be most often in the news. However, this has changed in recent years as severe fires have occurred in new areas, including parts of central Europe and Scandinavia, northern Canada and Alaska, Siberia, Indonesia and the Amazon region (Flannigan et al., 2009, Herawati & Santoso, 2011). In short, forest fires become a problem in places where they were relatively rare and harmless, while they become a major threat in countries where they have been present for a long time. Solving the problem is becoming a major challenge for policy makers and societies. In many countries this is reflected in significant changes in forest fire management in recent decades.

Past and present of forest fire management

As the problem of forest fires intensified significantly in the post II World War period, increased firefighting became the obvious answer and aerial firefighting rapidly increased. The surplus military aircraft used for aerial firefighting in the USA in the 1950s and 1960s, were soon followed by the Canadian-developed dedicated Canadair CL-215 amphibious water bombers, which were used in numerous countries around the world from the 1970s onwards (Mosov & Horskyi, 2022). Helicopters, which were used sparingly in the 1970s and 1980s due to high costs and limited availability, have been the most important tool for fighting fires from the air since the 1990s. In the late 1990s, a large and powerful ex-military helicopter, the Sikorsky S-64 "Skycrane" was converted into a very effective firefighting aircraft, the Erickson S-64 Aircrane, which can make a difference in firefighting but at a very high cost. The number of available S-64 Aircranes soon increased and they became part of the aerial firefighting fleet in many countries around the world. In the last three decades, some large well-known passenger aircraft (Boeing 747, McDonnell Douglas DC-10, McDonnell Douglas MD-87, Avro RJ85, Ilyushin Il-76, etc.) have also been converted to firefighting water or fire-retardant bombers, which carry huge loads and promise to extinguish large parts of fires with a single drop of water (Fojtík, 2019).

At the same time, firefighting on the ground became increasingly important. The number of firefighters grew, training improved, professionalism increased, and specialised units such as smokejumpers (Sowards, 2010), helicopters, and state-of-the-art "Type 1" crews were developed (Bramwell, 2008). Firetrucks became larger, more advanced and better equipped including provisions for self-protection. Tools at hand were improved and new tools were developed. Firefighter safety was recognised as extremely important, leading to the development of advanced clothing and other sophisticated personal protective equipment (Carballo-Leyenda, et al. 2021).

At the same time, technological developments were introduced at an ever-increasing pace. Forest fire spread models, developed through targeted research in the 1970s (Rothermel, 1972) were integrated into fire behaviour prediction systems in the 1980s (Burgan & Rothermel, 1984) and then, formed the basis for spatial fire spread simulation systems in the 1990s (Finney, 1998) that continue to evolve (Finney, 2006) and became useful tools for fire prevention and suppression. They soon became part of advanced computer-based systems that support the disposition of resources and the coordination of firefighting (Kalabokidis et al., 2012). Forest fire management tools were introduced in the 1950s, and have evolved over time to become another important tool in firefighting (Gimenez, 2004). Automatic fire detection cameras, and reconnaissance drones, are also among the important tools that have been introduced in many countries in recent years (Alkhatib, 2014; Yuan et al., 2015).

All these advancements in firefighting and technology promise to make fire

forest management more effective. Manufacturers promote their products with the promise that they can make a decisive difference in the effort to control all fires. Policy makers and other officials are eager to spend more money with the hope of preventing future disasters. Civil Protection is being strengthened everywhere, and the focus on firefighting is increasing year after year, especially after catastrophic fire seasons. As all of the tools and technologies mentioned above are associated with high cost, budgets for fire management are rising sharply in most countries. Unfortunately, in spite of the promises, the results are relatively poor and, in some cases, even marginal. Amazingly large fires occur nearly every year around the world. The average area burnt annually is not decreasing in most countries, and sometimes it is even increasing, in spite of the efforts, the equipment and the costs. The example of fire management statistics in the USA (1985-2018) is a proof of this (Fig 1): the number of fires is decreasing, the area burned is clearly increasing in spite of the sharp rise in the cost of firefighting.

Even more frustrating is the fact that every few years there is disturbing news about massive deaths among firefighters and citizens (Haynes et al., 2020; Xanthopoulos & Galloway, 2024). Entire countries are facing shocks they were not used to. It is clear that the approach taken to date is not producing the expected results and there is a strong demand for a solution to what has become a significant problem every fire season. Any such solution should be based on a good understanding of the problem, avoiding repeating the same measures as before, only on a larger scale. Policy makers should remember the saying attributed to Albert Einstein: "The significant problems we have cannot be solved at the same level of thinking with which we created them".

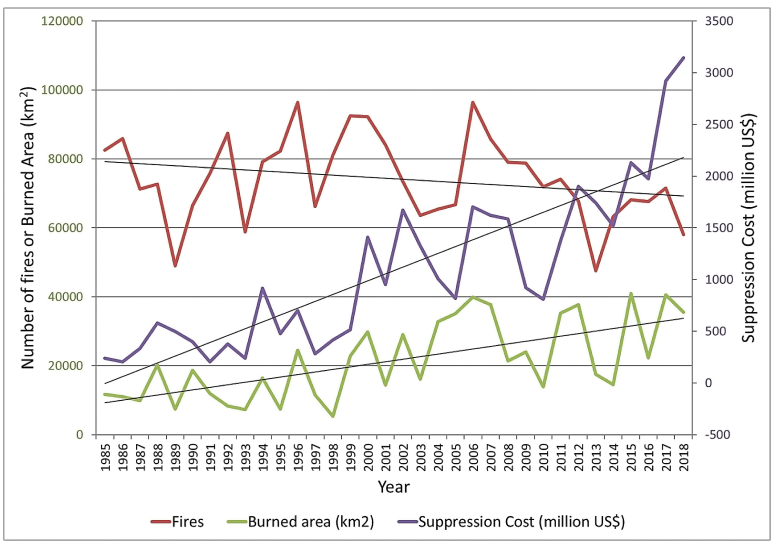

Figure 1. Evolution of the number of fires, the total areas burnt and the cost of suppression in the United States of America from 1985 to 2018 (Data source: National Interagency Fire Centre, Boise, ID, USA).

Why are forest fires getting worse?

In the face of ever-increasing strength of the firefighting mechanisms, their relatively poor results can only be attributed to the growing challenges associated with fire suppression (Calkin et al., 2015; Tedim et al., 2018). Scientific analyses concur with this and agree with numerous testimonies from citizens and firefighters. The main reasons cited for deterioration of the situation include:

1. Changes in climate and weather conditions
2. Failure to understand the dynamic evolution of forest vegetation and the natural role of fire:
   - Abandonment of rural areas, decline in rural population (Fig. 2), and reduced forest management leading to fuel accumulation (increase in fuel loads, horizontal and vertical continuity)
   - Fire suppression effectiveness increases future fuels! (Calkin et al., 2015, Kreider et al. 2024))
3. Changes in people's attitudes
4. Development of Wildland Urban Interface (WUI) areas
5. Inadequacies in fire prevention, including policies and regulations (Bouillon et al., 2020)
6. Potential inadequacies in fire suppression

As a rule, all of the above factors work together and increase challenges and risks for firefighters.

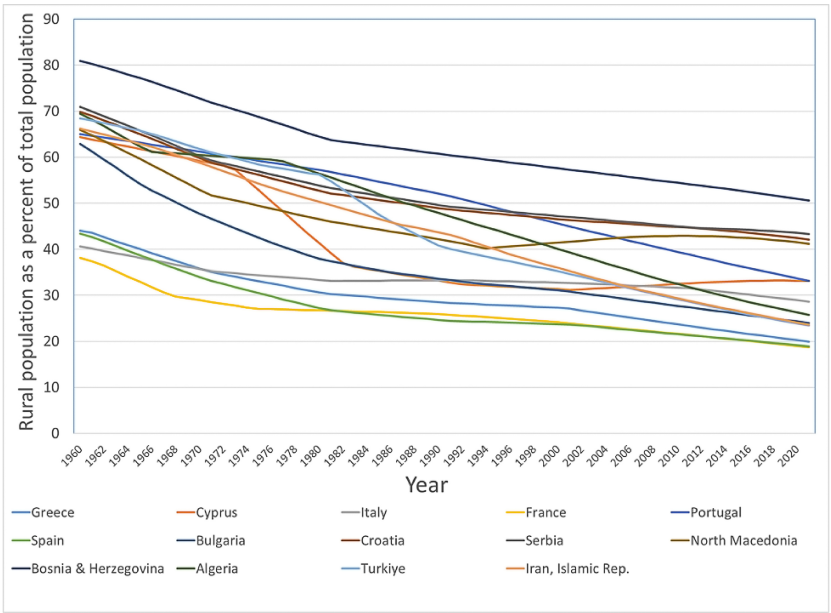

Figure 2. Rural population evolution as a percent (%) of the total population in fourteen countries in the Mediterranean, the Balkans and the Middle East.
(Data source: https://www.indexmundi.com/)

Climate change affects the weather in many ways, and not just through the observed rise in trend of the average temperatures. Changes in air, sea and land temperatures lead to changes in air circulation patterns, atmospheric profiles, the amount of water vapour in the air due to increased evaporation, etc. As a result, extreme weather conditions are becoming more frequent. The fire weather is affected accordingly, as periods of drought, heat waves with many consecutive days of very high temperature and low relative humidity, and days with extremely strong winds often coincide. The dryness of fuel combines with the wind. As a result, fires can easily start in the landscape, gain speed very fast, and the fire behaviour, both in terms of intensity and of rate of spread, becomes extreme very quickly (Jones et al., 2022). Extreme behaviour also includes phenomena such as fire whirls, profuse spotting (i.e., the creation of new fire starts outside the main perimeter of the fire by embers carried by the wind), the development of strong convection columns (Di Virgilio et al., 2019), etc. Under such conditions, firefighters can do very little and the result is large catastrophic forest fires. The term used to describe these fires, is megafire. It was coined in the 2000s (Williams et al., 2005) and refers to "fires that exhibit fire behaviour that exceeds all efforts to control, regardless of the type, kind or number of firefighting resources used".

How fires spread across the landscape also depends on the quantity and location of fuels. Fire suppression policies often tend to ignore the fact that forests, as

well as vegetation in rural landscapes, change dynamically as they grow through photosynthesis and eventually die. Dead biomass on the ground and in the tree crowns does not accumulate forever, but decomposes through the activity of invertebrates, such as worms and insects, fungi and bacteria. These microorganisms need a good combination of temperature and humidity to work effectively. If the climatic conditions in an area do not favour their activity and the rate of decomposition is slower than the growth of vegetation, fire is nature's way of accelerating the decomposition of dead biomass and maintaining long-term balance. The elimination of fire in forests adapted to frequent fire, leads to biomass accumulation (Stephens et al., 2018). In well-managed forests and rural areas, harvesting biomass as a product of the land (e.g., timber, agricultural products and animal grazing) helps to maintain balance and reduce the likelihood and intensity of fires.

In the last few decades, the rural population, as proportion of the total population has declined in most countries around the world. Rural areas are being abandoned while younger people are moving to large cities. At the same time, there is a general tendency to reduce forest management, as it is less profitable compared to other activities such as industry. This leads to an overall accumulation of biomass in the landscape in the form of increased fuel loads, which also have increased horizontal and vertical continuity, facilitating forest fire start and spread of large intensity forest fires that provid firefighting options. Increased firefighting capacity is an attempt to control the worsening fire problem. However, this leads to the so-called "fire paradox" phenomenon: successful fighting of landscape fires today, if not accompanied by effective forest management and agriculture to harvest biomass production, leads to further fuel accumulation, and more difficult fires in a few years' time (Kreider et al., 2024).

The population decline in rural areas is not only affecting the fuels in the landscape. As the average age increases, the ability of the local population to work on preventing and responding to forest fires, decreases. This includes, for example, lower maintenance of rural houses and insufficient control of the vegetation surrounding them to defend them in of the event of forest fire. This creates a rural-urban interface (RUI) problem, as many traditional villages become high fire-risk areas. On the other hand, the expansion of large cities to accommodate the growing population has led to the development of new suburbs where houses often come into contact or blend with vegetation. Furthermore, new tourist facilities, especially in the Mediterranean region, are often surrounded by flammable vegetation. In recent years, numerous and extensive "wildland-urban interface areas" (WUI) have been created. Fire risk there is very high. It is not surprising that devastating fires have occurred in many WUI settlements, sometimes resulting in fatalities.

All of the above factors contribute to the worsening situation with regard to fires in the landscape. Efforts to mitigate the problem should include actions aiming to address these factors as part of fire prevention. So far, however, this does not seem to be the

case, as shown by the funds earmarked for prevention in most countries compared to those spent on firefighting (Fernandes et al., 2020). Furthermore, prevention today is often seen as an activity that mainly involves technological means, from computers, maps and models to predict fire risks, to satellites, drones and surveillance cameras for rapid fire detection. The role of the people, the need to support them with policies that help them earn a decent living on the countryside, so that they can continue to live there, and the need to educate, mobilise and empower them to participate in fire prevention are often ignored. The importance of the existence of a strong and active forestry service is also overlooked due to the ignorance of decision-makers in some cases to the point of complete abolition, such as with the abolition of the Corpo Forestale dello Stato in Italy, in 2017 (Casinghini 2019).

Finally, there are many cases where firefighting authorities fall short of expectations (Fernandes et al. 2016). Although "the effectiveness of forest fire suppression is difficult to define, as it can be assessed against different objectives and at a range of scales" (Plucinski 2019), and generalisations can be unfair and ultimately invalid, there are a number of weaknesses that have been identified in many countries, especially where urban firefighters are involved in forest firefighting. Examples include: over-reliance on aerial resources to put-out the fires, while it is known that in most forest ecosystems final extinguishment has to be done by ground forces; aggressive firefighting tactics that do not take into consideration the temporal (diurnal) and spatial variations in fire intensity for safer, more effective and efficient fire control (Xanthopoulos et al., 2020b); use of larger diameter water hoses that are commonly used in urban firefighting but reduce agility in a forest environment where the fire spreads rapidly.

THE WAY FORWARD

With all the above pitfalls of the current approaches, the forest fire problem is likely to get worse if not properly addressed. Global change, which encompasses far more than just climate change, is likely to increase the current challenges. Existing policies to regulate forest fire, which are based on misguided approaches that are self-reinforcing, without considering or understanding the roots and dynamics of the problem, will only provide a short-term solution (Fernandes et al. 2020). Adapting forest fire management to the new reality is necessary, but it will not be easy. There are many challenges and barriers for the development of alternative solutions due to the complexity of the forest fire problem with its often conflicting environmental, technical, social, economic, and political aspects (Rego et al., 2018). Adaptations must address the public's ingrained belief in the currently prevailing fire suppression paradigm. They must overcome the influence and invested interests of industries that thrive under the ever-increasing paradigm of fire suppression. The social element of fire prevention should be promoted at least in par with the technological tools that can support fire detection, risk prediction, etc. The various actors should participate in

decision-making, including collaboration and coproduction of forest fire policies and initiatives at different levels, scales, and networks (Kirschner et al., 2023). The call of fire scientists and international organisations, such as the Food and Agriculture Organization of the UN, for integrated fire management (ECE & FAO, 2023), which includes a strong element of community involvement (Krah et al., 2020), should be adopted by public authority's leaders and politicians. This is a really difficult challenge, as they generally favour simple and clear "black-and-white" solutions, while fire management requires exactly the opposite. Furthermore, changes must not ignore the need of politicians to avoid major disasters during their relatively short term in the office, while fire prevention measures are likely to produce results in medium to-long term.

The pressure created by increasing fire disasters is influencing the way people think (Hartter et al., 2020) and is likely to be the motivation to address the above challenges and develop a new paradigm for landscape fire management that responds to the new conditions brought about by global change. There is no question that for such a complex multifaceted task it is necessary to use the knowledge and advice of science, always under the light of realism and practicability. One of these pieces of advice, focussing on the Mediterranean-type regions, is provided by Morreira et al. (2020) who proposed a change of paradigm. They suggested that extreme forest fires should be considered as unavoidable and more focus should be placed on minimising the damage they cause. They proposed to move away from using the area burnt to measure the impact of fire impacts on complex socio-ecological systems, and to use a more detailed multifactorial view for such an assessment.

The idea of minimising damage entails the need to create landscapes that are more resilient to the increasing risk of fire. Special emphasis should be placed on WUI and RUI areas in order to reduce the risk of damages there. The development of fire resilient landscapes and communities requires synergies between various state agencies and relevant stakeholders, working together and mobilising the local population (Xanthopoulos et al., 2023). In such landscapes:

- Maximum efforts are invested in minimising human caused fires (analysis and understanding of fires development, resolution of conflicts and technical problems, mobilisation of citizens, improvement of fire detection, maximisation of alertness according to predicted fire danger)
- Vegetation in agricultural and forestry areas is managed to minimise the risk of catastrophic forest fires, while achieving economic benefits to make the efforts sustainable and prevent rural population exodus
- Rural (and WUI) population is aware of the risk of fire and takes measures to protect themselves (e.g., preparing houses, planning action in case of fire). All relevant knowledge is made available to them
- Fire suppression is well organised, effective and efficient, and sufficient to protect

communities and the environment

- There is a fire prevention and protection plan in place, developed jointly with relevant local stakeholders, which sets out priorities and action protocols.

CONCLUSIONS

The need to approach the worsening forest fire problem under a different perspective, and to strike balance between efforts and funding for fire prevention and suppression is obvious. While the latter is quite straightforward, fire prevention is very complex and therefore a major challenge. To overcome the challenges, it is necessary to:

- Overcome ignorance about the true nature and complexity of the problem and promote prevention among the population in parallel to investments in technologies (e.g., fire danger forecasting, fire detection, technology-based training and dispatching, etc.)
- Inform and convince politicians, journalists, etc.
- Educate decision-makers in public authorities, who often follow the "business as usual" path
- Inform, sensitise and train the public; the majority are only interested for 2-3 years after a fire disaster
- Bravely stress not only effectiveness but also efficiency
- Limit the appetite of commercial companies to promote their products, by establishing criteria for actual need, and supporting decisions with objective cost-benefit analyses
- Empower those who need to apply the concepts (it is often forgotten that people are needed more than machines and that bureaucratic obstacles are often enough to null all good intentions)
- Foster cooperation at national and international level (sharing knowledge and experience, helping each other in difficult moments with firefighters, resources, and experts)

The alternative approach proposed above is more than likely to mitigate the current problems, improving people's resilience and safety while slowing down the continuous growth of the fire management budgets around the world.

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