Tropical Forest Issues

Issue No. 61, November 2022

Towards fire-smart landscapes

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Cover photo:	Brazilian fire manager setting a prescribed early burn in a Cerrado savanna landscape, Jalapão, Tocantins, Brazil. Photo: GFMC

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Preface

Catastrophic wildfires across the globe have been grabbing headlines in recent years. A 2022 report from the United Nations Environment Programme indicates that wildfires are growing in frequency, intensity, and spreading in range, with predictions of a 30% increase in the number of wildfires by 2050. Hotter and drier weather, next to changes in land use, are considered the main drivers. This stresses the importance of allocating more resources for preventing extreme wildfires occurring in the first place, alongside fire suppression after they have started.

National and local fire management strategies and implementation plans, in addition to supportive polices and regulations, are crucial components for an effective and coordinated approach. It is also vital that these measures be developed or revised at the landscape level. This should be done with all concerned stakeholders, in particular Indigenous peoples and local communities, who often hold critical knowledge of and experience in what works.

Acknowledging and understanding that the causes and impacts of wildfire are cross-sectoral issues, it is clear that fire management strategies need to engage ministries such as forestry, agriculture and the environment, as well as those responsible for health and infrastructure, among others.

In addition, noting how the reduction in wildfires will curb carbon emissions, there is a strong case to make to integrate fire management strategies into nationally determined contributions (NDCs) and other policies related to climate change adaptation and mitigation. In this way, countries would be able to access and mobilize climate funding for fire management, realizing their NDC ambitions toward fire-resilient and climate-smart landscapes.

In 2019 the Netherlands Ministry of Foreign Affairs made funds available to Tropenbos International to establish the Fire-Smart Landscape Governance Programme, with partners in Bolivia, Ethiopia, Ghana, Indonesia and Uganda. Through this programme, we have learned more about the varied roles that fire plays in different cultures and environments, that the application of inclusive and integrated fire management benefits people and forests, and that this can significantly support the achievement of climate, conservation, restoration and sustainable development goals.

This edition of *Tropical Forest Issues*, including 25 articles from 15 countries across the tropics, was produced as a part of this Tropenbos International programme, and adds to the global body of knowledge on integrated fire management. These experiences show that by combining fire science, traditional knowledge, adequate policies, community inclusion, landscape governance and capacity strengthening, it is possible to reduce the risks and impacts associated with wildfires and to give local populations a strong role in the management of their resources and the equitable governance of their landscapes.

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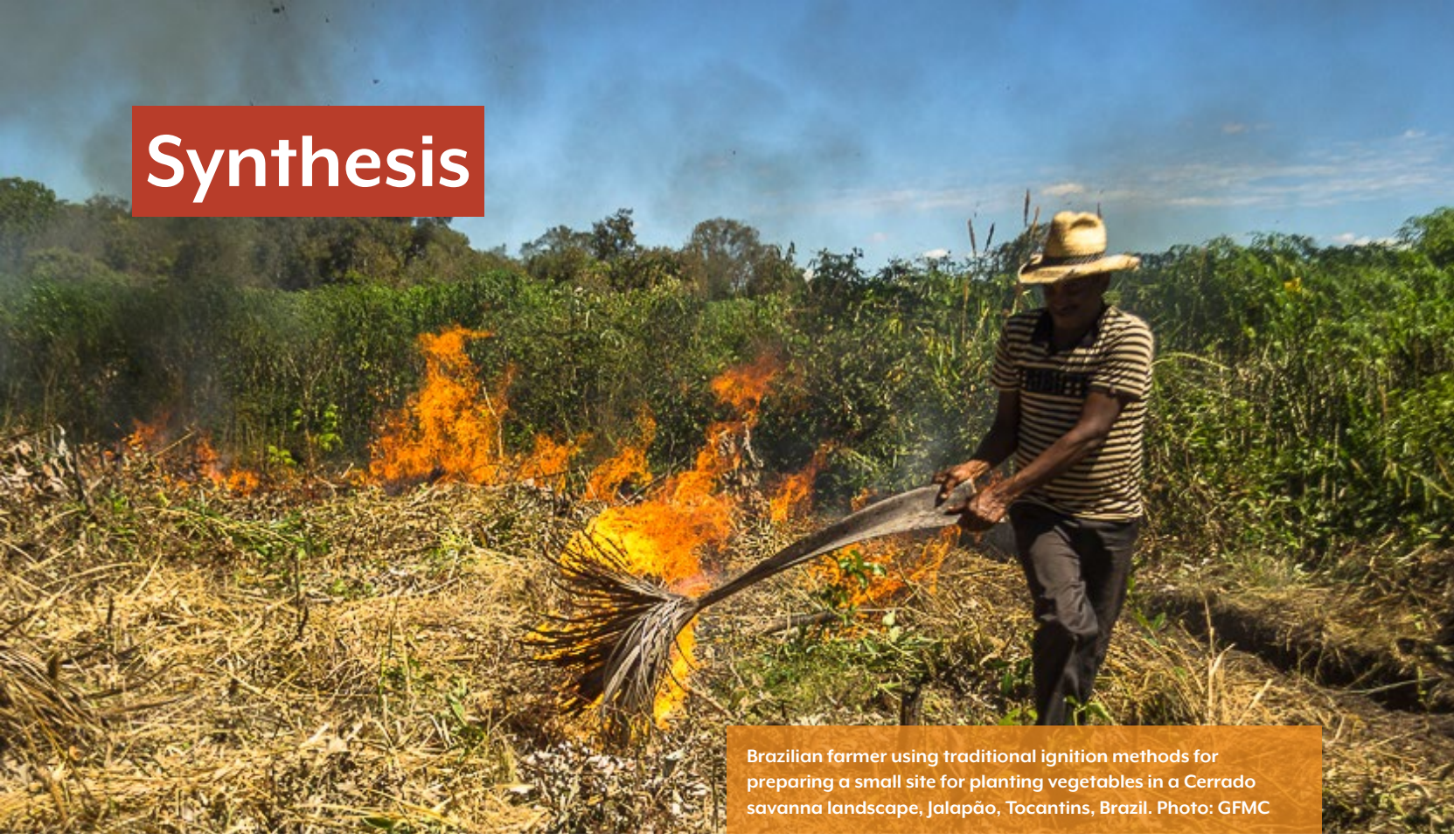
Synthesis



Brazilian farmer using traditional ignition methods for preparing a small site for planting vegetables in a Cerrado savanna landscape, Jalapão, Tocantins, Brazil. Photo: GFMC

The smoke clears... Global experiences in tropical fire management

Nick Pasiecznik, Johann Georg Goldammer, Bibiana Alejandra Bilbao, Atiek Widayati, Harifidy Rakoto Ratsimba, and Rosalien Jezeer

Prologue

The smoke clears... A small group returns to their homes for lunch. A few hectares smoulder, safely. This area won't burn again for some time. Alongside other patches burned at different times, the whole area is safe from the threat of a wildfire. Nutrients are returned to the soil. Fresh shoots will soon emerge for livestock. Snakes have fled from fields and homesteads; cattle ticks are gone, as well as other pests. The land is rejuvenated. This was the traditional way that people across the world managed fire, since the beginning of humanity.

But the first three words may have led readers to expect something quite different — charred remains of houses or whole towns, forests and animals; lives lost; towering flames; cars in queues; millions of dollars in damage; environmental harm; and a massive release of greenhouse gases (GFMC 2013a). Today, this is what we have become increasingly accustomed to reading about in the media from all over the world, and such catastrophic wildfires are predicted to only get worse and more frequent (UNEP 2022). What we are currently doing is clearly not working. We need to do something else, and quickly.

Implementing good prescribed burning practices has been proven to reduce the risks and impacts of extreme wildfires. It is a practice that must be reintroduced as part of coordinated integrated fire management (see Table 1) strategies, which will protect lives, lands and forests, and reduce emissions.

Table 1. Selected key terms used in fire management

Community-based fire management	A fire management system in which a local community (with or without the collaboration of other stakeholders) has substantial involvement in and responsibility for deciding the objectives and practices involved in preventing, controlling and utilizing fires. Often referred to by its acronym, CBFiM.
Controlled fire	Traditional / indigenous practices that are based on inherited experience. This differs from prescribed burning, that is based on advanced fire ecology science. *See also Prescribed burning*.
Firebreak	Any natural or constructed discontinuity that aims to segregate, stop or control the spread of fire, or to provide a control line from which to suppress a fire. It is characterized by a complete lack of combustible material. *See also Fuelbreak*.
Fire management	All activities required for the protection of forests and other vegetation from fire, and the use of fire to meet land management goals. It involves the strategic integration of knowledge — on fire regimes, probable fire effects, values at risk, level of forest protection required, cost of fire-related activities, and prescribed fire technology — into multiple-use planning, decision making, and day-to-day activities to accomplish stated resource management objectives. Successful fire management depends on effective fire prevention, detection, pre-suppression and control, having an adequate fire suppression capability, and consideration of fire ecology and human relationships.
Fuelbreak	Generally wide (20–300 m) strips of land on which less flammable vegetation is maintained and integrated into fire management, or where vegetation has been modified or fuel loads reduced so that fires can be more readily controlled (as distinguished from firebreak). In some countries, fuelbreaks are integrated elements of agroforestry systems that are intensively cultivated, grazed or subject to prescribed burning. Closed forests may contain fuelbreaks known as "shaded corridors," where stands are intensively thinned and pruned. Fuelbreaks also have the advantages of preventing erosion, and offering a safe place for firefighters to work. *See also Firebreak*.
Integrated fire management	A system that includes one or both of the following concepts: (1) integration of prescribed natural or human-caused wildfires and/or planned application of fire in forestry and other land uses in accordance with the objectives of prescribed burning; and/or (2) integration of fire management activities and use of the capabilities of rural communities/land users to meet land management objectives.
Landscape fire	A fire burning in vegetation of natural and cultural landscapes, e.g., natural and planted forest, organic terrain (such as peatlands), shrub, grass, pastures, agricultural lands, and peri-urban areas, regardless of ignition sources, damages, or benefits. *See also Wildfire*.
Prescribed burning	Controlled use of fire to reduce fuels (in either their natural or modified state), under specified environmental conditions, which allows the fire to be contained to a predetermined area and at the same time to produce the required intensity of heat and rate of spread to attain planned resource management objectives. Early burning is a form of prescribed burning conducted early in the dry season before leaves and undergrowth are completely dry and/or before leaves are shed, as a precautionary measure against more severe fire damage later on. *See also Controlled burning*.
Wildfire	Any unplanned or uncontrolled fire burning in vegetation of natural, cultural, industrial, and residential landscapes, which regardless of ignition source (i) may require suppression response, or (ii) other action according to agency policy, e.g., allowing the fire to freely burn as long as it meets land management objectives. *See also Landscape fire*.
Wildland fire	A North American term used internationally, "wildland" includes all burnable vegetation resources, including managed forests and plantations. Since "wildland" does not have a corresponding term in languages other than English, alternative terms are preferred (vegetation or landscape fire, or specific terms such as forest, grassland, agricultural or pasture fires).

Box 1. Issue highlights

Tropical Forest Issues No. 61 (formerly *ETFRN News*) includes 26 articles, including contributions from 100 co-authors (Pasiecznik and Goldammer 2022). Following a call for abstracts reviewed by a seven-strong panel of experts, case studies were selected from 15 countries in tropical America, Asia and Africa, along with articles summarizing the ecology, management and concepts related to fire management. This synthesis draws out common lessons and recommendations.

Highlights include the following insights. Local participation is crucial, for all parties to share their perceptions of the problem, and to jointly design and implement fire prevention and suppression. The importance of indigenous and traditional knowledge of fire management emerges strongly, especially in Latin American articles. Innovative cases are presented, such as the use of agricultural fuelbreaks, with potential for scaling, if land rights are secured. Equitable landscape governance as seen in indigenous territories was also importance for successful fire management. Capacity development for fire management is also needed at all levels, from national and subnational coordination to community volunteers — and not just for dedicated fire brigades. Where lacking, national integrated fire management strategies, policies and action plans must be developed, with cross-sector collaboration, clear roles and responsibilities, and resources for effective fire prevention and suppression. What is also clear is that "no fire" policies introduced in many countries have been counterproductive, and have actually contributed to more intense wildfires. Thus a shift is urgently needed, from a focus on suppression to one on prevention and integrated management, including the controlled use of fire. Finally, expansion of international efforts is needed, building on well-established organizations and networks, for generating, collating and sharing experiences.

As the smoke clears, we see the urgent need to better acknowledge and incorporate the knowledge and practices of the people described at the start of this story. The use of prescribed fire is just one subject highlighted in this review (see Box 1). It does not intend to fan the flames of polarized debates but does aim to put out the embers that underlie the misinformation that continues to support the prevalent mindset of decision makers.

Fire management terminology

To avoid confusion and ensure clarity it is essential to have agreed terminology, and in multiple languages. The generally accepted global fire management glossary (GFMC 1999) includes terms in Spanish, French and Russian (FAO 2010). This was revised and updated from the first multilingual consent-based Wildland fire management terminology, in English, French, German, Italian and Spanish (FAO 1986). Over the past 20 years, fire management terminologies have been published for Europe, Australasia, North America and Central Asia (for all available glossaries, see GFMC 2017). The terms in Table 1 are based on those in published glossaries.

The history of "no fire" policies

Hunters, farmers, shepherds and other land users all over the world have routinely used fires to manage vegetation throughout history of humanity. Today, the prevailing perception of land management authorities seems to be that "all fire is bad." What happened to cause this seismic shift in thinking? That story starts 200 years ago. Much has been written on this and there are numerous versions of historical events (Pyne 2021); though some may argue the details, the following provides an indication of how this change in mindset occurred.

In temperate and Mediterranean Europe, natural (lightning-caused) fire is not a factor that has shaped natural ecosystems. However, the use of fire in land management has a long history and has significantly shaped cultural landscapes, including ecosystems of high conservation value. However, a complex mix of cultural and power relationships led to the emergence of the view that fire use by land users should be discouraged.

During the era of European colonialism, indigenous fire practices were largely replaced by unsustainable burning by settlers, and in some cases traditional practices were even outlawed, perhaps as a way to exert control and power over indigenous peoples. Prohibitions continued as countries gained independence, and bans even expanded, such as in Latin America in the 1900s, with the implementation of "zero fire" or "zero burning" policies [see 2.1]. In Brazil, the Forest Code of 1934 was the basis of the country's fire prohibition policy, which considered traditional fire practices as an enemy to be fought [2.2]. In South and Southeast Asia, the "fire schism" in India, Indonesia and Myanmar (Burma) was reviewed (Goldammer 1993).

Community member in Ecuador conducting prescribed fire . Photo: Amazonía sin Fuego Programme

During this time, the extent and severity of wildfires in some countries coincided with a number of significant changes in land ownership and use, and migration. These changes included both the settling of "new land," especially in the tropics, and the abandonment of rural areas, which was common in the Mediterranean, for example. A major factor was the use of exclosure measures that gave ownership of large tracts of previously communal land to individuals (or companies), and that limited or even prohibited access by local people. This was a common occurrence during the colonial period, alongside the discouraging or banning of traditional burning practices. There was also extensive clearing of forests for the expansion of agricultural and pastoral land, and for new settlements.

The cultural value of fire became lost in many parts of the world, the less people saw fire. And since the 1800s, first in Europe, then across the world, those who benefitted most from land-use changes also appeared to be those who proposed that all fire was "bad." Today, even after a single generation, children are growing up without even seeing the benign use of fire, and are likely to believe the new narrative. In parallel, more people have moved to urban areas, and there have been movements for increased conservation (land needs protecting, fencing, keep people out, let nature take over), but nature burns, naturally. Most recently are concerns regarding carbon emissions, and they seem to oppose the use of any fire. However, as with the misplaced aims of those concerned with conversation regarding fire use, climate change mitigation also would benefit from judicious use of prescribed fire, which reduces the risks of catastrophic wildfire.

Today, the wider reintroduction of prescribed fire to reduce wildfires is promoted by many. This is a challenge to established patterns of land management. However, in the face of ever greater and more frequent extreme wildfires, the pressure is on governments across the world to make this change. In the USA and Australia, for example, there are decades of experience in bringing back prescribed burns (e.g., Pyne 2021). The same trend is observed in Europe, particularly in the management of cultural landscapes (GFMC 2013b). And after the unprecedented wildfires of recent years, further reconsideration of increasing the use of prescribed fire in land use management could be expected.

The emergence of tropical fire science

The earliest scientific work in the understanding of fire was related to the chemistry of combustion, with Antoine Lavoisier's work, which began in 1772, and Joseph Priestly's discovery of oxygen in 1774. This was followed only much later by advances in the ecology of fire and by much more interest in fire management, with developments throughout the 1900s coalescing into a deeper understanding of the role of fire in tropical landscapes (e.g., Nye and Greenland 1960; Goldammer 1988; Steensberg 1993).

The first major step toward combining the previously fragmented knowledge of fire in the tropics and

subtropics into a transdisciplinary, interdisciplinary, holistic science and approach came in 1989, at the Third International Symposium of Fire Ecology (Goldammer 1990). This highlighted that at least 600 million hectares of tropical and subtropical forest, savanna, bushland and grasslands were then affected by fire each year, and that the area of uncontrolled wildfire was increasing, due in part to the conversion and clearing of forests. The impacts were already evident — severe forest degradation, loss of species, and soil erosion leading to siltation and flooding in lowland areas — and were also seen then as a source of smoke particles, CO_2 and other trace gases impacting atmospheric stability and global climatic change (Crutzen and Goldammer 1993).

There were significant advances in the subsequent three decades, with fire science emerging as a transdisciplinary discipline. Overviews of the current state of knowledge on the role and history of fire in tropical landscapes [1.1] and fire management practices [1.3] are summarized in this volume, alongside the related roles of organizations and people that link the two components [1.2].

In parallel, developments fundamental to fire management have occurred. The field of remote sensing, with the availability of ever-higher-quality satellite imagery, allows users to detect active fires and determine burned areas. However, such data still requires ground-truthing to confirm its validity — or increasingly, the use of drones — to improve the accuracy of the resulting information [4.7]. The misinterpretation of "hotspots" also needs to be addressed (see Box 2). Nonetheless, when these measures are combined, and use the latest computing technology, monitoring systems can be developed that are of great use to land managers in planning fire prevention and suppression actions [4.3].

The re-emergence of traditional knowledge

The value of traditional knowledge of fire use is a recurring theme throughout this volume. In certain regions, this traditional use has been acknowledged for some time, such as with the firestick community in Australia, and in North America, where traditional knowledge has been drawn on for the partial reintroduction of prescribed burning (Pyne 2021). In the tropics, however, the value of this knowledge is only now re-emerging. This volume provides a rich source of evidence that supports the need to work closely with indigenous peoples and local communities, and learn

Box 2. Not all hotspots are wildfires

Online fire information systems can generate maps that supposedly display only active fires. However, satellite data shows all high-temperature events — active vegetation fires, yes, but also industrial combustion and heated surfaces. Screenshots show (a) a global map with active fires as red dots, often referred to as "hotspots," a term that leads to further misinterpretation of the true nature of fires. Zooming in on sub-Saharan Africa (b) has the appearance of a burning subcontinent, but is merely a composite of many thousands of small-scale agricultural fires, among wildfires in open lands and forests. In the Middle East (c), many red dots are gas flares.

Satellite-derived information about active fires becomes more valuable when it is supported by land cover map overlays; e.g., the ESA Worldcover dataset (10-m resolution). Such layers allow users to carry out more reliable and detailed analyses, such as evaluating environmental impacts and risks, and determining priorities for management, related to land coverage and the types of vegetation involved.

from their age-old practices, in order to manage fire effectively.

In South America, this is seen clearly in articles from Venezuela [2.1]. Brazil [2.2], Mexico [2.3, 2.7], Argentina [2.4], and Bolivia [2.6; 2.8] A particularly pertinent example in seen in Venezuela, where patch mosaic burning by the indigenous Pemón people in the country has been assessed in long-term scientific trials and proved to be effective in reducing wildfire risks, and is now being taught to firefighters by the Pemón [2.1]. In Brazil, prescribed fire has been shown to have positive effects on faunal diversity [2.9]. Results from Brazil and Australia also prove that implementing prescribed burns based on traditional indigenous practices effectively reduces the spread and number of wildfires, along with the resulting greenhouse gas emissions (Mistry et al. 2018; Russell-Smith et al. 2013).

The importance of the cultural aspects of fire also comes out strongly in a number of articles, especially for Mexico [2.3; 2.7]. These two articles are the first publications to use the term "pyrobiocultural" — incorporating the concepts of biocultural landscapes and biocultural diversity. When analyzing the important roles, uses, benefits and impacts of fire in a landscape, it seems appropriate to have a specific term that implicitly integrates the diverse social, cultural, environmental and economic components of fire [2.3].

The need for supportive policies

Effective and supportive government policies are crucial in reducing wildfire risks. This is particularly noted in articles from Asia. The benefits from policies and regulations and their enforcement are evident in Viet Nam [3.2], where the number of fires and the total area burned in 2018 was one-third of the totals 15 years previously. The area under plantations has been increasing at the same time; protecting commercial plantations was an important incentive for the government.

In Indonesia, the massive application of fire in land-use change and the resulting wildfires in 2015 led to the establishment of new bodies and to the enactment of the Forest and Land Fire Prevention and Suppression regulation and associated regulatory instruments and technical guidelines [3.1]. The focus was specifically on preventing further peatland fires, which caused severe smoke pollution throughout the region, and which released millions of tonnes of CO_2. There have also been advances at the provincial level, such as the Directive and Provincial Guidelines for Fire Prevention, enacted in West Kalimantan in 2020 [3.5]. Also in Indonesia, since the enactment of Law No. 32 in 2009 and the use of evidence from satellite images and ground verification in court cases, most cases against those who caused illegal fires have been won. That has led to a large reduction in illegal fires [3.3].

The importance of a national fire management strategy is highlighted for Nepal [3.6]. And where polices are lacking, it is notable that national needs analyses saw a national strategy as the principal and overarching requirement. This was the case in Ecuador [2.5], Ethiopia [4.4] and Uganda [4.6]. Furthermore, since wildfires do not respect boundaries, the need for more regional coordination is clear, with positive advances in South Asia [3.6], Eastern Africa [4.7], and South America [2.1, 2.5].

Community inclusion

Most contributions stress the importance of involving local communities in fire management planning, prevention and suppression. In Latin America, most of the cases emphasize community involvement, specifically of indigenous groups (see above). In Africa, notable articles are from Ghana, where a private plantation company works with local communities to protect its plantations, along with farms, villages, natural forest and communal land [4.1], and where an NGO has reduced wildfire risk through inclusive fire management [4.5]. Also in Africa, the innovative approach of using agricultural firebreaks has proved effective in Madagascar, thanks to working with communities to achieve mutual benefits [4.2]. In Asia, community involvement is emphasized as key in Thailand [3.4] and Nepal [3.6] and is a cornerstone of reducing fire risk in Indonesia [3.1; 3.5].

The Global Fire Monitoring Center (GFMC) portal on community-based fire management (CBFiM) (https://gfmc.online/manag/cbifm.html) reveals rich expertise in community inclusion and participatory fire management. Here it can be seen that advancements in applying the principles of CBFiM have been made in the tropics. This is opening a window of opportunity for non-tropical countries to also benefit from these experiences.

Landscape governance

Strongly linked to the success of active community involvement in planning and implementation, is that land ownership, access and resource use rights are clear. Landscape governance is particularly important over large areas of savannas and forest lands that are (or were) under de facto common or community ownership. Two cases from Bolivia show this need clearly, and how the formalization of Indigenous territorial rights and

governance were key to improving fire management [2.6, 2.8], The importance of respecting indigenous or local communities' territorial governance systems was also explicit elsewhere in the Americas, notable in Argentina [2.4], Brazil [2.2], Mexico [2.3] and Venezuela [2.1]. Securing tenure rights was also observed as key for the success of agricultural firebreaks in Madagascar [4.2], and for community land management in Thailand [3.4] and was implicit in others.

To successfully reduce fire risk, a landscape vision is needed that incorporates the varied perspectives of all those living or working within that landscape. This can be achieved using a framework of integrated landscape approaches that simultaneously support development, conservation and climate objectives (Chavez-Tafur and Zagt 2014), and that can also reduce wildfire risk. This also needs to include the governance of land-use change, especially regarding conversion of forest or savanna for plantations, cultivation or grazing. In order to better address the causes of wildfires, landscape approaches must recognize the relationship between fire and society and consider the complex interactions between the different factors and actors behind the use of fire.

Capacity strengthening at all levels

A common theme in many articles is the need to strengthen capacity at all levels. At the level of national and regional governments, there is a need for an improved understanding of the role of fire, the value of local knowledge, and the benefits of integrated fire management, in order to reduce wildfire risks. This need for capacity strengthening is not limited to ministries responsible for forestry and the environment; it also includes ministries of agriculture, health and social affairs, among others.

National fire agencies and their regional and local staff would benefit from training in new technologies, and in the use of traditional fire management. Capacity strengthening is especially required at the local level, where community volunteer brigades may have no experience in preventing or suppressing fires. Training is an essential prerequisite to ensure personal safety as well as effectiveness. All those who will be active in fire suppression require training in the appropriate equipment; this equipment must also be provided.

Combining approaches

Effective integrated fire management requires a combination of these elements — fire science, traditional knowledge, supportive policies, community inclusion, landscape governance, and capacity strengthening — as well as active interaction with policy makers. How this is done will of course depend on the specific situation in each place. The diversity of experiences presented in this volume provides a range of examples.

In Indonesia, integrated landscape approaches — supported by policies and with the full participation of communities — are proving effective in reducing wildfire risks while also restoring peatland areas [3.1]. The articles

Training in fire related policies and regulations in Ghana. Photo: Rosa Diemont

from Ghana provide examples of combinations of various elements, such as communities partnering with a private timber company [4.1] and an NGO [4.5]. In Thailand, community-based management of both fire and water is helping to decrease wildfire risks, following ethical approaches promoted by the king and the adoption of technology for improved monitoring of air quality [3.4].

In Bolivia, integrating people, knowledge and good practice is paying dividends [2.6], as is basing fire management on indigenous governance systems [2.8]. In Venezuela, fire science is proving that traditional burning practices are effective; indigenous communities and firefighters are sharing knowledge and skills [2.1]. In the Cerrado savanna of Brazil, institutional partnerships support the development of research and the improvement of tools for integrated fire management activities [2.2]. In Ecuador, the government has taken the lead, with international support, incorporating the five components discussed above: fire science, traditional knowledge, supportive policies, community inclusion, landscape governance, and capacity strengthening [2.5]. This approach is also seen in Mexico, where it shows the potential to reduce the risk of wildfires in a national park [2.3], and has been adopted to reduce smoke and air pollution in Mexico City [2.7].

Each situation requires different components in different proportions, to be applied at different times. In terms of the benefits of integrated fire management (IFM), and the practices to employ when applying IFM approaches, a toolbox of approaches is well summarized in the introduction [1.3]. The introduction also provides numerous source publications that go into much more detail on each approach.

The review of people and organizations involved in improved fire management [1.2] proposes three fundamental requirements before deciding on engagement methods: (i) evaluating the natural and ecological aspects of fire in the landscape; (ii) understanding the institutions in charge of fire management, for prescribed fires or wildfires; and (iii) working with communities, listening to them and understanding how they interact within the landscape. The article also notes, however, that considering just these three factors before making fire management decisions could give an incomplete impression of what is required, with the reality being much more complex.

Implementation on the ground must be informed by good fire science and thorough field experience by those making decisions. These actions must be well coordinated and adequately resourced at the local and district level, within the framework of a comprehensive cross-sector national policy and implementation strategy. Only when all these components are in place will integrated fire management be effective.

Recommendations

The effects of wildfires — and the measures needed to manage them — are as varied as the people and landscapes that they affect. The following recommendations summarize the immediate needs, from international to landscape level.

International level

- Fire management must be acknowledged as a cross-cutting, interdisciplinary science and practice that advises and informs decision making in international debates, agendas and actions.
- Implementing integrated fire management is urgently required and must be encouraged by international organizations across sectors and governmental agencies.
- An international framework for integrated fire management must be established, based on proven and innovative principles of fire management and governance (see Council of Europe 2022).

Regional level

- Intersectoral and intercultural platforms between countries should be supported, for exchanging information, experiences, tools and capacity building in fire management.
- Resources should be provided to existing and active regional networks and centres, to increase information sharing on fire occurrences, resources and disaster-response capacities.
- Since fire impacts (including air pollution) are cross-border issues, improved regional coordination is required, including mutual cross-boundary assistance for managing wildfires.

National level

- National fire management strategies, policies and regulations — implemented in a coordinated manner — must underpin all efforts to reduce wildfire risks.
  - » Where these measures already exist, they should be revised as necessary in the light of new knowledge, with adequately resourced action plans adapted to local contexts, and involving knowledge and practices from local communities as well as professional expertise

  - » Where these measures do not yet exist, countries should develop them as a matter of urgency in an inclusive, participatory and intersectoral manner, including all relevant ministries, local governments, community organizations, NGOs, research institutions, and the private sector, where applicable.
- Wildfires are disasters that affect every aspect of life, and risk reduction needs to be incorporated into planning by ministries of agriculture, forestry and the environment, as well as those responsible for health and infrastructure, among other sectors.
- Countries need to urgently consider the application of integrated fire management as a component of the actions needed to meet their nationally determined contributions (NDCs).

Landscape level

- Communities, especially in fire-prone areas, must be encouraged to take responsibility for fire management in their jurisdictions, including the use of traditional practices, supported by the provision of training and equipment.
- External support for capacity strengthening, especially for community volunteer brigades, is essential. This must include training in fire prevention and suppression, among other skills. Adequate and appropriate equipment must also be provided.
- Addressing wildfires, landscape approaches must recognize the relationship between fire and society, and consider the complex interplay between the actors, factors and fire.
- Successful models of wildfire-resilient landscapes that are locally managed for production and conservation must be documented, replicated and scaled.

Conclusions

Conclusions from many articles in *Tropical Forest Issues* No. 61 are supported by evidence gathered in past decades that fire exclusion alone has not reduced wildfire risk. Far from it, in fact; it can result in higher fuel loads, which increase the risk of more catastrophic fires (e.g., Bilbao et al. 2020; Pyne 2021). However, some still incorrectly see fire exclusion policies as the best option, so there is an urgent need to change this paradigm.

The challenge ahead is to convince sectoral actors to break free of institutional silos and move towards horizontal, cross-cutting cooperation and shared responsibility in addressing the complex realities of integrated fire management. This must be accompanied by changes in national and international approaches to fire management, and land managers, project managers, officials and politicians must take into consideration the overwhelming evidence that supports integrated fire management when they develop and implement more effective fire management plans. The media can also become a great ally in this process, by not simply reporting on catastrophic wildfire events, but by communicating pioneering and successful experiences on implementing integrated fire management.

The articles add to the expanding global knowledge on integrated fire management. They show how fire science, traditional knowledge, supportive policies, community inclusion, landscape governance and capacity strengthening, when suitably combined, will lead to a future with less destructive fire, in part by encouraging the wise use of benign fire. The fire management expertise presented in this volume, opens the door to new and promising solutions to climate change mitigation and adaptation, by learning from and preserving cultural heritage and diversity and developing future-oriented nature-based solutions. Importantly, fire management globally may benefit from the experiences in tropical countries.

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Section 1

Introduction

Photo, previous page: Community member with personal protective equipment and backpack pumps conducting prescribed burning of understory vegetation, Terai, Nepal. Photo: Sundar Sharma

Typical surface fire in a dry dipterocarp forest, Thailand.
Photo: GFMC (K. Wanthongchai)

1.1

The role and history of fire in tropical landscapes

Johann Georg Goldammer

"Fire management solutions and decision making must be based on historic and contemporary scientific-technical evidence."

Introduction

Globally, most landscape fires occur in the tropics and subtropics, where natural, lightning-caused fires have favoured the evolution of characteristic plant communities in sustainable fire ecosystems. Indigenous communities developed traditional burning practices for land management, especially in fire-adapted and fire-dependent tropical savannas and deciduous forests. Traditional small-scale slash-and-burn agriculture is still practised in fire-sensitive ecosystems such as equatorial rainforests, peatlands and wetlands.

Fire is also increasingly used for large-scale conversion to agro-industrial plantations and grazing land, and this, as well as maintenance burning of newly created open landscapes — such as recurrent use of fire in cattle pastures or for removal of agricultural residues — is a major source of uncontrolled wildfires. These often spread to surrounding land, including

fire-sensitive forests and protected areas, leading to severe degradation of ecosystems and loss of forest cover.

The characteristics, impacts and severity of fires vary, depending on land use, intensity of utilization and associated degradation. For example, secondary vegetation on degraded tropical forest lands, such as the vast areas of *Imperata* grasslands (*Imperata cylindrica* in Southeast Asia and *Imperata brasiliensis* in South America) that are highly flammable and where frequent — often annual — wildfires occur. In conjunction with increasingly extended droughts due to climate change, these landscapes suffer excessive burning, degradation and loss of vegetation cover.

Intensive agricultural and grazing systems result in the fragmentation of tropical and subtropical landscapes. Rural communities and individual farmers and pastoralists have a high interest in protecting their land, villages and other assets against the adverse effects of wildfires, and where the safe use of fire and wildfire prevention measures often results in a significant decrease in the number of wildfires and area burned. In regions where rural populations and especially youth are urbanizing, there is underutilized or abandoned land subject to plant encroachment and ecological succession, where invasion of flammable secondary and seasonally vegetation leads to increasing wildfire hazard and risk.

While landscapes and fire regimes — the typical occurrence of fire in an ecosystem as characterized by seasonality, return intervals, behaviour and severity — vary over regions and time, there are historical constants. Fires have affected the vegetation of the planet for more than 400 million years, long before the advent of humans. Besides the direct effects of fire on ecosystems, fire-generated emissions are part of global biogeochemical cycles and have always influenced the chemistry of the atmosphere. In the 1980s, interactions between fire, tropical forests, savanna, climate and climate change arose as a major focus of interdisciplinary research (Goldammer 1990; Crutzen and Goldammer 1993; Goldammer 2013); see Figure 1.

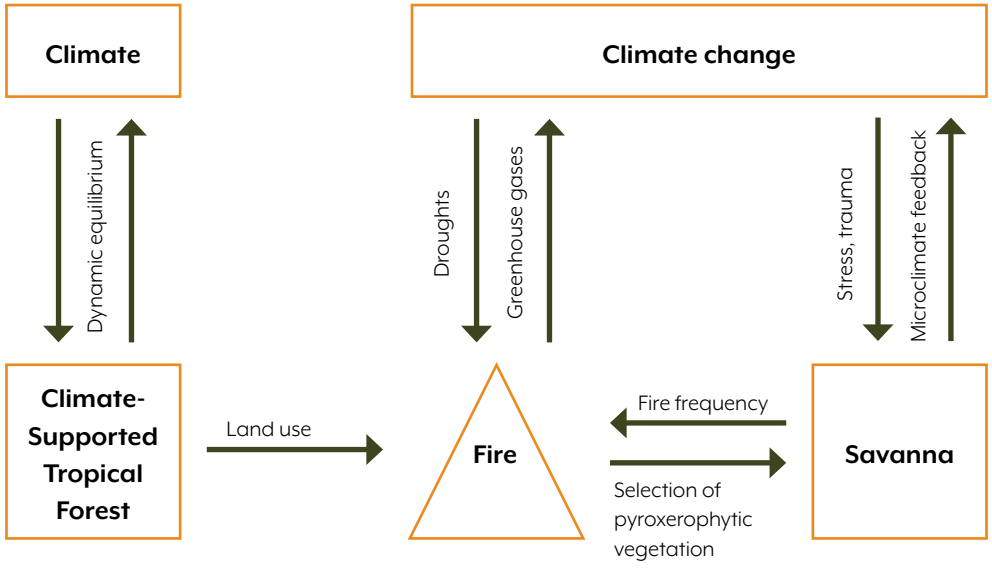

Figure 1. Interactions between fire, tropical vegetation and climate, developed at the first global forum on the role of fire in the tropics and its global implications. Source: Goldammer (1990)

History of fire in the tropics

Charcoal fragments in coal seams (fusain) provide evidence of fire in ancient forests from the Carboniferous Period. Radiometric age determination of charcoal found in Amazon rainforests reveals prehistoric natural or early-human-caused fires in the Holocene (ca. 3500–6000 years BP). In Southeast Asia, charcoal samples from lowland rainforests in eastern Borneo were dated to the peak of the last Pleistocene glaciation, ca. 18,000 years BP (Goldammer and Seibert 1990).

During the Pleistocene, the role and influence of fire on vegetation may have changed in accordance with climatic fluctuations. During interglacial periods, the prevailing warmer and more humid climate created conditions that were unfavourable for fire. During glacial epochs that occurred for some 80% of the last two million years, the tropical climate was cooler, more arid and seasonal than at present. This caused rainforests to retreat into refugia, surrounded by savanna-type vegetation that was likely to have been strongly

influenced by fire. Such fire "corridors" between refugia may have contributed significantly to the genetic isolation of present-day rainforest "islands."

In Africa, early humans used fire for at least 1.5 million years, and this spread globally, becoming a dominant factor that especially influenced tropical vegetation, as shown by pollen analysis. In seasonally dry regions adjoining humid equatorial rainforests, fires were set for hunting, to improve grazing, and to keep land open for security (improved visibility) and accessibility. Neolithic fires played a role in opening closed forest ecosystems and savannization, and the reasons for and methods of fire use have changed little since then. Today, however, unprecedented human population pressure, consequences of climate change, and changing fire regimes mean that the influence of fire is now a critical element in the development of tropical vegetation and a predominant driver of degradation and destruction.

Tropical fire regimes

Fire regimes in tropical forests and derived vegetation are characterized and distinguished by fire frequency, seasonality and behaviour (intensity/severity). Tropical and subtropical fire regimes (Figure 2) are determined by ecological and anthropogenic (socio-cultural) gradients. Lightning is also an important cause of natural fires, which influenced savanna-type vegetation in pre-settlement periods, and are observed in deciduous and semi-deciduous forests and occasionally in rainforests.

However, with increasing human activities, the contribution of natural ignition to overall tropical fire occurrence is becoming less significant, compared to

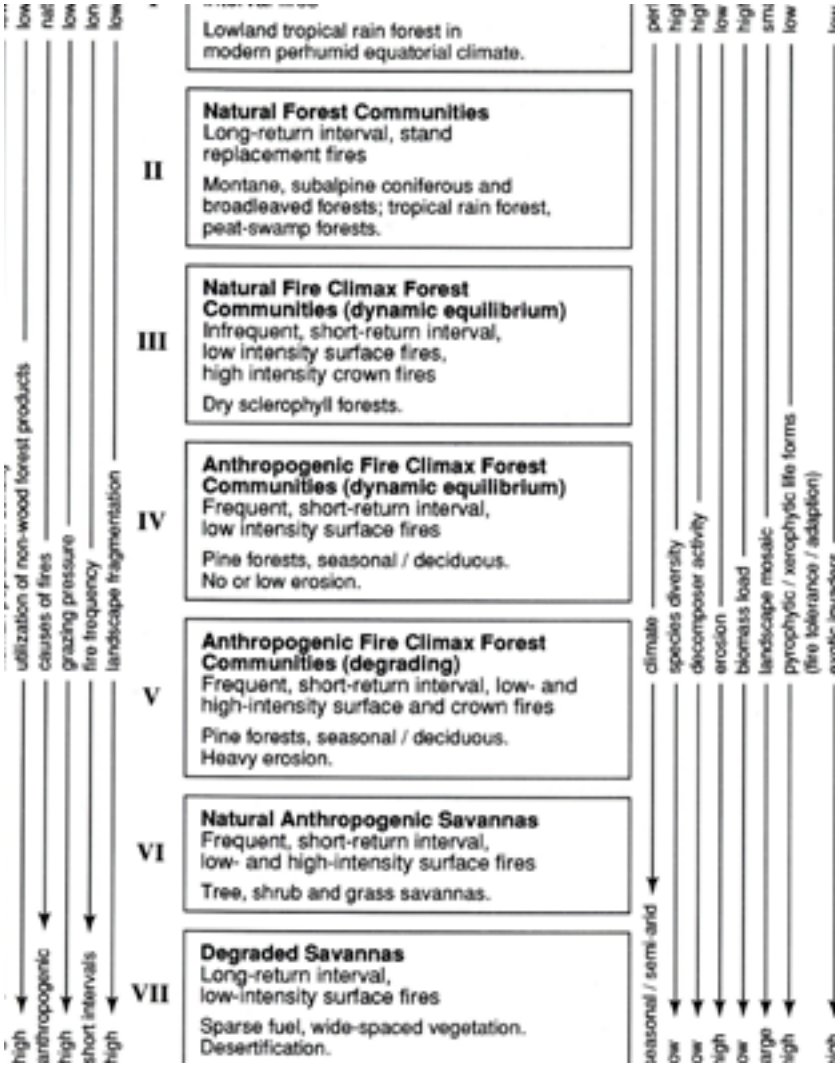

Figure 2. Types of tropical/subtropical fire regimes, related to ecological and anthropogenic gradients. Note: there are exemptions to this generalized scheme, such as higher species diversity in certain fire climax communities. Source: Goldammer (1993)

Effects of a forest-conversion fire after clearing a lowland dipterocarp forest in East Kalimantan, Indonesia. Photo: GFMC

human-caused ignitions or fires purposely set for the following main reasons (see also Goldammer and de Ronde 2004).

- the most convenient and inexpensive tool for converting forest and other native vegetation (including wetlands and peatlands) to other land uses; e.g., agriculture, plantations and pasture, or exploiting other natural resources (open-cast mining);
- traditional slash-and-burn agriculture;
- grazing land and pasture management; i.e., fires set by hunters and herders, mainly in savannas and open forests, and by managers of industrial livestock enterprises;
- harvest of non-timber forest products; i.e., the use of fire to facilitate harvesting or improve yields of plants, fruits, etc., predominantly in deciduous and semi-deciduous forests;
- fires that start at the interface of residential areas;
- traditional fire uses such as religious, ethnic and folk practices; and
- targeted or collateral consequences of conflicts over land-use rights or territorial sovereignty.

The following sections discuss the role and history of fire in five generic forest types: equatorial rainforests, seasonal forests, tropical highland and subtropical lowland pine forests, savannas and open woodlands and planted forests.

Fire in equatorial rainforests

These are fire-sensitive ecosystems, where the main issue is the use of fire for forest clearing:

- slash-and-burn agriculture, where small forest areas are temporarily converted to agricultural use before being allowed to return to forest vegetation after a relatively short period; and
- conversion to plantations, cropland and pastures (or other non-forestry land uses), where large forest areas are permanently changed.

Clearing and burning always follow the same pattern. Trees are felled at the end of the wet season, and to improve burning efficiency, vegetation is left for some weeks to dry out. In undisturbed rainforests, the efficiency of the first burning varies and may not exceed 10–-30% of aboveground biomass, as only a small amount of the biomass in the tree trunks is consumed. The remainder is treated by a second fire or is left at the site to decompose.

Slash-and-burn farming provided a sustainable system for indigenous forest inhabitants, and the patchy impacts had limited effects on the overall tropical forest biome. Today, it is still practised in many topical regions, but is becoming increasingly destructive because of population pressures, which lead to larger cleared areas and shorter fallow (forest recovery) periods. In addition, large areas of primary and secondary rainforest are increasingly being converted for plantations, agriculture and grazing land in many regions of the tropics (Page et al. 2013; Cochrane 2013).

Targeted fire use in rainforests often results in wildfires that escape control. The impact of drought and fire on Borneo and the Amazon rainforests since the 1980s show that undisturbed vegetation may become flammable. Cases of rainforest fires associated with droughts were reported in Borneo in the 1800s and 1900s, and during the 1982–83 drought, numerous fires spread beyond forest conversion and shifting agriculture areas, affecting approximately 5 million ha in East Kalimantan, Indonesia, and the Malaysian provinces of Sabah and Sarawak (Goldammer and Seibert 1990). The 1997–98 fires in Southeast Asia resulted in a total burned area of 5 million ha in East Kalimantan, including 2.6 million ha of forest that burned with varying degrees of damage (Heil and Goldammer 2001; and Siegert et al. 2001).

Forest regeneration after fire shows no coherent pattern. Although dipterocarp forests tend to be highly fire-sensitive, there is regeneration potential where burning is moderate. However, recurring fires in rainforests lead to degradation over time by successively reducing forest cover and species diversity, and finally, with the invasion of pyrophytic grasses. Large tracts of former tropical lowland rainforests are now degraded *Imperata* grasslands, maintained by fires with a short return interval.

Fire in seasonal forests

The occurrence of seasonal dry periods in the tropics increases with distance from the equatorial zone. Rainforests gradually transition to open, semi-deciduous and deciduous monsoon, moist and dry forests. Between

Fire-induced destruction of a lowland tropical rainforest in East Kalimantan, Indonesia.

(a) Pristine dipterocarp rainforest (1980); (b) surface fire following selective logging (1982); (c) post-fire stage with some trees still standing (1985); (d) post-fire stage after more trees have died and undergrowth now dominated by pioneer species, highly flammable in extremely dry years (1995); (e) after a second, high-intensity fire (1998); and (f) final stage of savannization, and invasion by *Imperata cylindrica* (1998, on a frequently burned site nearby). Source: Goldammer et al. (1996) and Goldammer (1999). Photos: GFMC

Left: Typical pure stands of fire-resistant sal (*Shorea robusta*); and right: teak (*Tectona grandis*) in northern India that result from fires occurring every 1 to 3 years, eliminating competing tree species. Photos: GFMC

more closed deciduous forests and grass savannas, a broad range of ecotones are found. As varied terminology is used to describe non-evergreen forests and transitions to savannas, the prevailing fuel type is more appropriate for distinguishing diverse formations (Goldammer 1991, 1993).

The term "forest" is used where trees and woody matter dominate the fuel mix. The main fire-related characteristics of forests are seasonally available flammable fuels (grass-herb layers and shed leaves), which allow the understorey (grass and shrub layers) and overstorey (tree layer) to survive and even take advantage of the regular influence of fire. Adaptive traits include thick bark, ability to heal (fire scars), resprouting capability (coppicing, epicormic sprouts, dormant buds, and lignotubers), and seed characteristics (serotiny, or seed release after fire, dispersal, dormancy, etc.) (Stott et al. 1990; Goldammer 1993). These features are characteristic elements of a fire ecosystem.

Deciduous trees shed their leaves during the dry season, creating an annual source of surface fuel. In addition, the layer of drying and dried grass, together with the shrub layer, add to the available fuel, which generally ranges between 5 and 10 tonnes/ha. Herders, hunters and collectors of non-timber forest products usually set fires to burn the forest floor to remove dead plant material, stimulate grass growth, and facilitate or improve the harvest of forest products. Fires usually develop as moderately intense surface fires and can spread over large areas. The canopy layer is generally not affected, although isolated crowns may burn earlier in the dry season before leaves are shed. In some cases, fires may occur in the same area several times per year; e.g., an early dry season fire that consumes the grass layer, and a subsequent fire that burns shed leaf litter.

The ecological impacts of annual fires on deciduous and semi-deciduous forests are significant. Fire strongly favours fire-tolerant tree species, which replace other species that would grow in an undisturbed environment. For example, many monsoon forests in continental Southeast Asia would return to evergreen rainforest if human-caused fires were eliminated. This effect has also been observed in Australia when aboriginal fire practices and fire regimes were controlled, and rainforest vegetation started to replace fire-prone tree-grass savannas.

Tropical deciduous forests largely constitute a "fire climax"; i.e., their composition and dynamics are predominantly shaped by fire. However, they are not necessarily ecologically stable, as the long-term impacts of frequent fires lead to considerable site degradation. For instance, erosion tends to be significant due to depletion of the protective litter layer by fire just before the onset of monsoon rains. In India, fire adaptations and the fire dependency of economically important trees such as sal (*Shorea robusta*) and teak (*Tectona grandis*) have been the focus of discussions regarding fire control policy since the colonial period.

Fire in tropical highland and subtropical lowland pine forests

Of the more than 100 species of pines, some extend into the tropics, but none occur naturally in tropical Africa or in the whole of the southern hemisphere (except Sumatra). Tropical pines are largely confined to lower montane rainforest zones, usually on dry sites with a seasonal climate. Most are pioneers and tend to occupy disturbed sites such as landslides, abandoned lands and burned sites. In the subtropics, pines are also found in lowlands.

Most tropical pines show distinct adaptations to fire, with thick bark, taproots, some sprouting post-fire, and highly flammable litter. Tropical fire-climax pine forests, largely the result of a long history of regular burning, are found throughout Central America, at mid-elevations of the southern Himalayas, and in submontane elevations throughout much of Southeast Asia. As in tropical deciduous forests, fires are generally started by herders, hunters and collectors, but they also spread from the careless use of fire in farmland. The increased frequency of human-caused fires has led to an overall increase of fire-adapted pines and pure pine stands outside their natural area of occurrence in a non-fire environment. In tropical montane zones, fire also leads to an increase in altitudinal distribution, expanding mid-elevation pine forest belts into lowland rainforests and higher-altitude broadleaved forests.

Subtropical fire-climax pine forests are also the result of a long history of natural and anthropogenic fires. In North America, the belt of southern pines stretches from the subtropical coastal area along the Gulf of Mexico into southern temperate forest regions. Pines that may dominate or form pure stands are in permanent competition with more fire-sensitive broadleaved trees. Pines gained a competitive advantage with regular natural lightning-caused fires, and with historic fires set by the pre-Columbian population and later by European colonists. This fire regime was disturbed, however, by the influential European dogma of fire exclusion, which was inappropriately imposed on North America in the late 1800s, and on many other areas in the world. In the 1970s, US public policies were further modified, this time aiming to re-establish natural and human-shaped fire regimes through the reintroduction of prescribed burning practices, and by allowing some wildfires to burn within fire management objectives.

In tropical and subtropical regions, fire-climax pine forests can support large human populations. If managed properly, fire creates highly productive forests that can provide sustained supplies of timber, fuelwood, resin and grazing. However, the increasing occurrence of wildfires — coupled with overgrazing and excessive logging — tends to destabilize submontane pine forests, resulting in forest depletion, erosion and subsequent flooding of downslope catchments.

Fire in savannas and open woodlands

The various types of natural savannas are shaped by their edaphic, climatic and orographic origins and by wildlife (grazing, browsing and trampling) and fire (Cole 1986). Alongside anthropogenic influences

Left: A young *Pinus khesyia* stand on a steep slope in Luzón, the Philippines. Right: an open stand of *Pinus roxburghii* on the Himalayan slopes in Uttar Pradesh, India. Large tracts of such pine forest are subject to severe erosion due to the effects of regular fires and overgrazing. Photos: GFMC

such as livestock grazing and harvesting of fuelwood and non-timber products, most tropical savannas are also affected by regularly occurring human-made fires (Figure 3). The interactions of wildlife, humans and fire throughout history are significant in the development of tropical savannas, and modern analyses have always regarded the role of fire as especially important.

Figure 3. Generalized scheme of closed dry deciduous forest degradation and rehabilitation, as induced by uncontrolled fire and grazing (regressive) and protective measures (progressive). Adapted from Verma (1972)

Many tropical humid savannas are stable fire climax ecosystems, such as humid Guinean savannas in Côte d'Ivoire that are subject to regular fires. The extreme fire tolerance of palms (here: *Borassus aethiopum*) is a pantropical phenomenon. Photo: GFMC

Left: A typical fuel load of needles in a 9-year-old *Pinus ellliottii* plantation in Brazil, with a "ladder" of aerial fuels and a lack of understorey. Right: Surface fuel load in a 15-year-old *Pinus taeda* plantation after the third thinning. Photos: GFMC

Concerning fire ecology, the distinction between savannas and open forests can be based on potential fuel availability. In grass savannas, the grass layer is the exclusive or predominant fuel, whereas in open deciduous forests the predominant fuel is tree leaf litter and woody material from the tree layer. In open savanna woodlands (tree savannas), grass is also an important surface fuel.

Fuel availability varies with the various bioclimatic and phytogeographic savanna zones (Menaut et al. 1991). In the arid West African Sahel, aboveground biomass is 0.5–2.5 t/ha, increasing to 2–4 t/ha in the mesic Sudan zone, and up to 8 t/ha in the humid Guinea zone. Fire frequency largely depends on fuel continuity and density. Thus, savannas with relatively high and continuous loads of flammable grasses, such as those in the Guinea zone, are subject to shorter fire-return intervals than arid savannas. In addition, burning efficiency depends on the moisture content of dead and live organic matter, so fires in the early dry season generally consume less aboveground biomass than those at the end of the dry season.

Fires in planted forests

Forest plantations in the tropics are established for three main purposes: (i) to support the demands of local people for timber, fuelwood, non-timber forest products, etc., (ii) for landscape rehabilitation or environmental protection; e.g., greenbelts, shelterbelts, erosion control and sand stabilization; and (iii) to establish industrial monoculture plantations for timber, pulpwood or oilseeds, almost entirely with exotic species (commonly, pine and eucalyptus). Litter production in plantations of fast-growing species is extremely high, and with the exclusion of other forest uses leads to an accumulation of surface fuels (thick layers of needles/leaves, woody debris, shed bark) and aerial fuels (shed needles, leaves and twigs that are caught in branches).

Within their natural range, both pine and eucalyptus have developed forest formations that are largely shaped by natural and human-made fires. Regularly occurring fires suppress fire-sensitive vegetation and favour the formation of pure stands. Exclusion of fire from these fire-climax ecosystems generally leads to a build-up of fuels and an extreme wildfire hazard, where high-intensity fires are likely. Similarly, they were established as plantations without considering or introducing recurrent fire as a basic element to stabilize the biological disequilibrium in fuel dynamics. Consequently, many of these plantations are also highly susceptible to high-intensity fires.

The introduction of prescribed fire into tropical plantations, or the reintroduction of fire into fire ecosystems where fire-free management systems have been applied, remains a necessary but challenging field of practice and requires changes in fire management policy (Goldammer and de Ronde 2004).

Conclusions

Globally, the role of natural fire in ecosystems, and of cultural fire in land management, has been explored widely. This article provides an overview of the many roles

and impacts and roles of fire in different environments in and around tropical forests, and while not exhaustive, it shows that fire management solutions and decision making must be based on historic and contemporary scientific and technical evidence.

There has been substantial progress in understanding the application of fire management approaches in which local communities act in their own interest to maximize the benefits from the appropriate use of fire and to avoid damage caused by wildfires. Unfortunately, only a few countries have put in place fire management policies and practices that address the underlying causes of the excessive and harmful application of fire where it is not appropriate.

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Forest fire fighting using hand tools. Photo: Pak Doni

1.2

Fire management – the dynamics of organizations and people

Brett Shields

"Extreme wildfire events can be analyzed, understood and better managed by learning from the past, to enable fire organizations and people to take positive steps forward."

Introduction

The growing number of wildfires around the world is an indication that something has upset the balance of nature. Climate change is one driver, but human fire management and decision making across the landscape is a larger and stronger influence. Wildfire occurrences cannot be passed off as being purely driven by climate change. Humans are responsible, and must play a role in finding and implementing solutions, and quickly.

The impacts in both developed and developing countries alike are obvious — large tracts of land burned by wildfires, smoke pollution, and lives and housing lost. Climatic factors that drive extreme wildfire events are not a surprise to land managers, as they are cyclical and predictable. Coupled with this is the influence of mass media and politics, searching for alarmist headlines rather than stories of low-profile or long-term planning that drives solutions. This can create negative feedback loops by encouraging

politicians to seek quick wins rather than considered, longer-term decision making; this can exacerbate fire disasters. Furthermore, land and disaster agencies are applauded for their heroic response efforts, and rightly so, but often within those same agencies there remains inadequate emphasis on preventing fire disasters in the first place. Such imbalances, and the human choices behind them, show that something is wrong, although we have the capacity to make positive changes.

The fire historian Stephen Pyne eloquently places the global perspective into what he calls the "pyrocene," which we have created and must learn to live within. His concept includes three paradoxes (Pyne 2021). The first is that the more humans try to remove fire from landscapes that have coevolved with fire, the more violently fire will return. The second is that even as wildfire disasters gather more media attention, the total area of land burned is actually diminishing. Third: while striving to reduce carbon emissions, the planned and intentional burning of some landscapes will have to increase.

There will undoubtedly be more large-scale wildfires if the status quo prevails (Kurvits et al. 2022). This article assesses what can be done by land managers, communities and politicians to make better decisions that reduce fire risk and impacts. It does so by discussing the 'how' and the 'who' of fire management – organizations (institutions or agencies, formal or informal) and people (impacted by fire or those working in of such organizations).

From past to present

The drivers of wildfire in any place and at any point in time result from the combined influence of climate and vegetation and fire ecology, coupled with the influence of humankind in all its manifestations, and the use, or not, of prescribed fire. To understand landscapes today, it is useful to differentiate fire in human history in three approximate periods: the Holocene epoch (~11,000 to 250 years BP), the industrial period (~250 to 20 years BP), and the present day (~20 years BP to present).

Considering a landscape, its vegetation and its natural- or human-induced fire occurrence over time helps to reveal the interactions of humans and ecology. This allows for an understanding of the impact of circumstances on wildfires in the past as compared and contrasted to today, when something is clearly amiss (Figure 1). History does not tell the story of wildfire disasters as we see and feel them today. Records do not tell of communities ravaged by wildfire, but of those that worked with fire and lived with fire in order to manage their needs and the wider landscape. So, what has changed from the past to today, and what is it that we cannot see or seem to grasp.

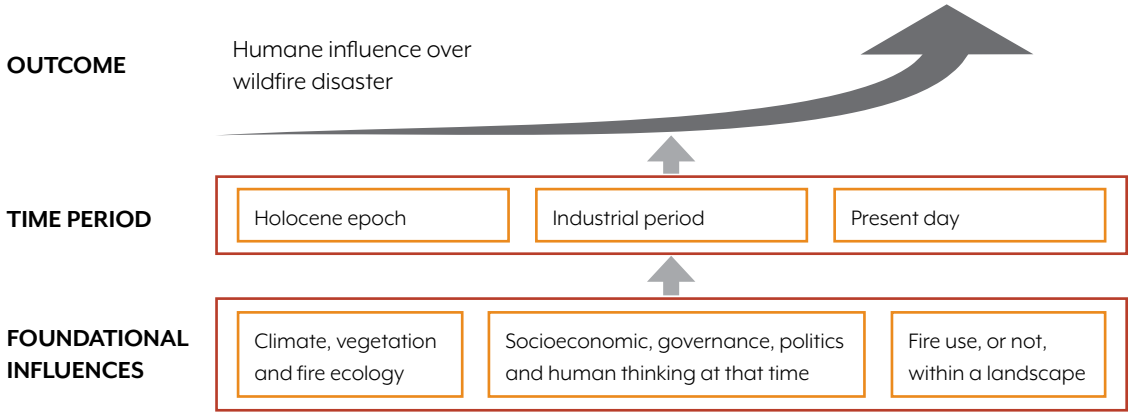

Figure 1: Factors that influence wildfires over time

In Australia, for example, indigenous culture and the practice of burning were almost wiped out under European dominance and influence. However, there is now a resurgence of indigenous cultural awareness that also includes the reintroduction and use of prescribed and traditional fire techniques (Firesticks Alliance n.d.). In Indonesia, some indigenous Dayak communities still use prescribed fire in a manner akin to that used 400 years ago. They prepare land by creating firebreaks, and light a planned and controlled fire to clear an area for planting. However, prescribed fires in this context still create dangers from smoke pollution, and cannot and should not be used in certain ecologically sensitive areas or on soil types such as peatlands.

Every place across the globe has its own story to tell in terms of the use, misuse, understanding and misunderstanding of fire within and across the

landscape. Land managers need to successfully navigate that knowledge and understand and characterize their landscape and situation, no matter how appropriate or inappropriate the use of fire seems at that time, to comprehend it in terms of balance within the local ecology. Only once this is understood can the next steps be taken to better manage fire with a landscape.

The "how" and the "who" of managing fire

It is usual to refer to the "who" first and the "how" second, but considering the evolution of fire management and events to the current day, this normal order is reversed. In the past, when discussing organizations, their policies, plans and practices, the core facet of 'the people' was often overlooked. More frequently today, however, people are included as an integral component of community-based forest management, indigenous fire management and 'living with fire'. Such 'people discussions' can be devoid of organization to a certain level, and as such, are presented afterwards.

Assessing "who" manages fire attempts to describe the group of people or stakeholders involved in decision-making processes and fire management practices. Assessing "how" people manage fire and attempts to describe the organizational models (formal or informal) involved. When considering these two facets, there is also a multitude of influencing factors to think about, such as the landscape context (fire tolerant, fire intolerant or fire interdependent), economic development of the country/region, and presence (or not) of institutional structures to manage fire.

The split into these two categories, organizations and people, is not clear in the literature. There are elements of overlap, but dividing the discussion, however, allows for a more structured thought process for making better management decisions regarding the implementation of fire management practices across a landscape. Three different management approaches are introduced: local; landscape; and territorial (or jurisdictional). See Table 1.

Table 1. The "how" and "who" of fire management

How	Who
Organizational measures that address fire management activities (prevention, suppression, etc.).	*The group of people who discuss and decide on fire management activities within their various settings.*
Local approaches	
These include community wildfire protection plans (CWPPs) and community protection plans (CPPs).	CWPPs and CPPs are often used in developed countries and in the wildland-urban interface (WUI), e.g., in the US and Australia. They are mainly used to organize local people with activities and possibly equipment to help protect and defend against wildfires. Community-based fire management (CBFiM) is predominantly a process to engage people, often used with developing agrarian societies. It is not an organizational process, but an engagement approach.
Landscape approaches	
These include integrated fire management (IFM) and integrated forest fire management (IFFM).	IFM and IFFM are holistic approaches to manage wildfire using prevention, preparation, suppression response and recovery. They involve people from institutions or organizations that have legal or regulated jurisdictions, such as forestry companies, government, and conservation or fire agencies. They can also benefit from improved community engagement processes.
Territorial approaches	
This includes fire-smart territories (FSTs). It must be noted, however, that this concept is theoretical at present, and its practical application still in the trial phase.	FST includes a people-empowerment approach, but has not yet been applied in the field. *Living with fire* (see Stoof and Kettridge 2022) is a relatively new approach that involves the breadth and diversity of inclusion needed to better manage complex fire situations. This author has aligned that concept to the increasingly wider requirements of the FST approach, but this could be constrained at a landscape scale, or even at local levels.

Organizational models – the "how"

Fire management organizations and institutions can be local or national; formal (regulatory or statutory) or informal (community or locally determined); involve paid or volunteer staff; and include land management agencies (public or private) or civil protection/disaster management agencies (public or NGO). No one size fits all, but there are common principles, practices and pitfalls. The need to be both specific and adaptable in terms of management and organization in any one landscape cannot be underestimated. Also, simply transplanting an organizational approach from one location to another has repeatedly been shown to fail.

The following questions should be asked:

1. What is the scale being considered? Is it community scale, one that encompasses a village, a landscape type such as a peatland hydrological unit, or a jurisdiction such as a district or province?
2. What regulated institutions or unregulated organizations are currently working on fire management? Do they have legal mandates, are they bounded by regulations to perform only certain activities, do they address the needs of the whole landscape, and do they meet the needs of local communities? Note that although it is often perceived that only a large or regulated organization can manage fire well, history has shown otherwise.
3. What are the gaps in and local needs for fire management? Is it support to prevent fires igniting; to mitigate the spread and impact of unwanted fire on human or ecological values; for firefighting and suppression; to reintroduce fire to a fire-tolerant or fire-dependent ecology; and/or to develop more fire-resilient infrastructure and livelihoods?

Local approaches

These include community fireguards, community wildfire protection plans, and land management plans (which usually require people to undertake actions in their region). Usually applied at the household, village or suburb level, they are often supplemented by professional fire services that support fire management activities in the surrounding landscape, including firefighting if a wildfire does occur. These approaches are common in regions where property and lives have been lost as a result of fire. They are also common in places where professional fire services have difficulties protecting high-value assets such as houses adjacent to vegetated areas, often referred to as the wildland-urban interface. This tends to occur in locations where people do not make their living from the land.

In rural areas, there are fewer professional fire services to support or participate in planning, and when a fire does occur there is also limited capacity for government fire service response. Local approaches are often governed by community interactions with an NGO or local company, who develops a fire management plan with the community. This may incorporate components such as participatory mapping, use of a local fire-danger scale to monitor when it is appropriate to ignite a fire, and various kinds of suitable firefighting equipment. These types of planning constructs are often informal, and are used to varying degrees across other tropical countries.

Landscape approaches

Initially known as integrated forest fire management, this was introduced in Indonesia in the early 1990s as part of a project supported by the German government (Schindler et al. 1996). The range of activities across the spectrum of fire management was not as complete as it is today, but did include facets of prevention, pre-suppression, suppression and prescribed or controlled fire. However, a literature review of national wildfire management capabilities in Thailand in 2000 could not find an effective institutional design of a land management agency that was appropriately balanced to build or guide fire-management capabilities (de Mar et al. 2000).

In response to this gap, a structured basis for integrated fire management was developed, borrowing the concepts of prevention, preparedness, response and recovery from the emergency management sector, and adding a problem-analysis stage. This stage is a crucial first step to understand the fire context within a landscape; it is needed to guide the development and implementation of activities to improve the situation. Frameworks of IFM as an organizational construct emerged in the 2000s (Arbor Vitae 2003; Myers 2006) (Figures 2 and 3). These were designed to lead to ecologically and socially appropriate, as well as organizational, approaches to managing fires and to address fire-related issues.

Myers (2006) added an adaptive management feedback loop (Figure 3), and expanded the approach to be relevant at local, national and even multi-national scales. Arbor Vitae's five-step framework later became the 5Rs of fire management: review, risk reduction, readiness, response and recovery (FAO 2011).

A Framework for Fire Management

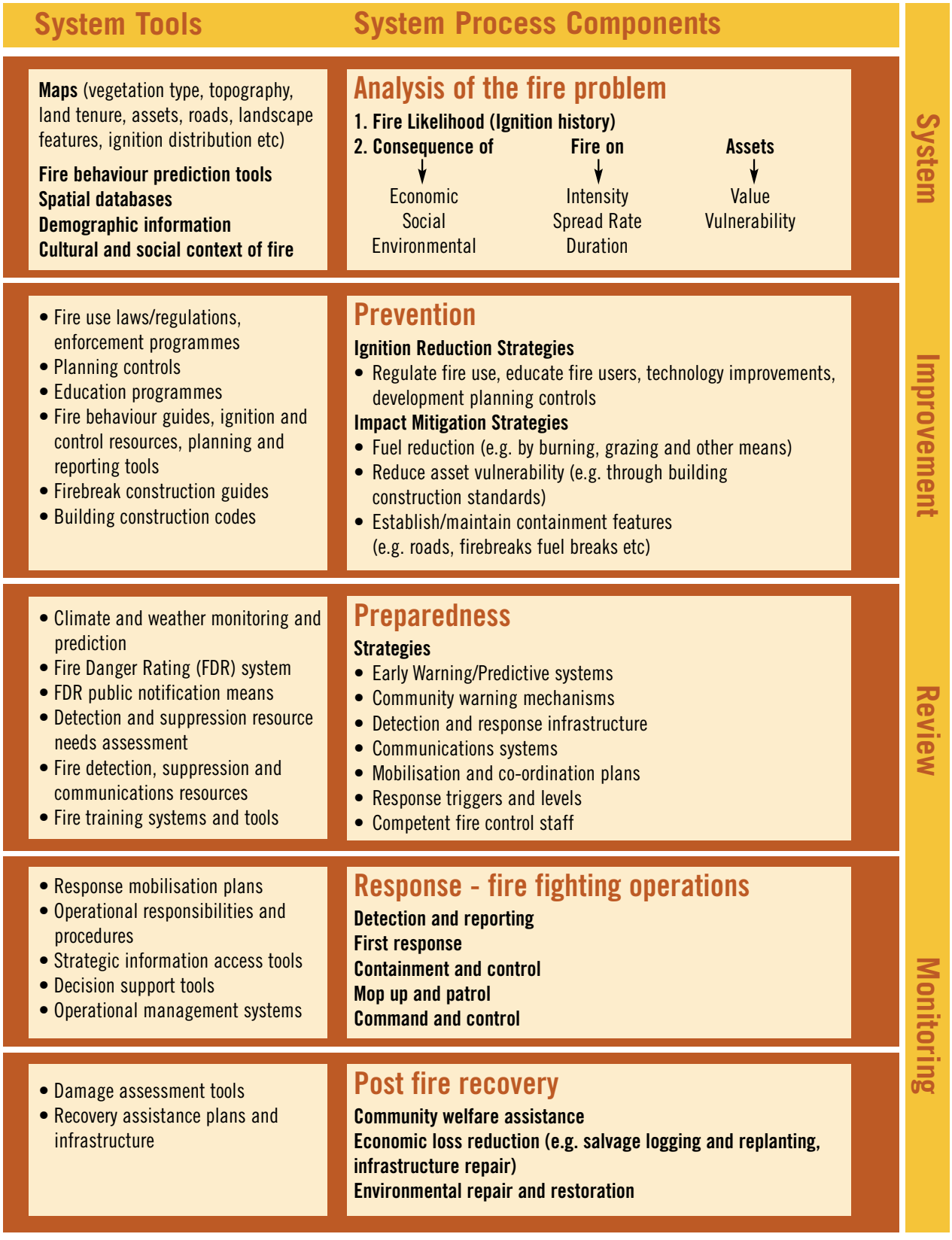

Figure 2: A five-step framework for fire management. Source: Arbor Vitae (2003)

Figure 3: Schematic of an ecologically driven integrated fire management solution. Source: Myers (2006)

The European Fire Paradox project introduced IFM as part of its aim to simultaneously consider actions to both reduce the damage caused by fire and promote the benefits of fire use, and to achieve this using a balanced approach called integrated fire management (Rego et al. 2010; see Figure 4). European adoption of IFM is targeted to rebalancing fire use within landscapes as a traditional and ecologically appropriate tool, and to reintroducing fire as a firefighting tool, such as using a backfire to stop the spread of a wildfire.

Figure 4: Schematic of the process to reintroduce prescribed fire in Europe using integrated fire management. Source: Rego et al. (2010)

IFM is valuable to different people in different contexts, but there does not appear to be a singular defining use. However, when looking at the four different versions of IFM — a project design concept (Schindler et al. 1996), an organizational design tool (Arbor Vitae 2003), an ecological balancing approach (Meyers 2006), and a reintroduction of prescribed fire (Rego et al. 2010) — each seeks a holistic balance and an appropriate use (or absence) of fire in a landscape, and adopts an approach that is more than just suppression-based. IFM uses inclusive language and approaches that can be adapted to integrate all aspects of fire management in a landscape.

Territorial approaches

More recently, the fire-smart territory (FST) approach was developed as a new construct for the organizational management and appropriate use of fire, alongside the need for inclusive dialogue (Tedim et al. 2016). This approach explicitly works to understand fire management by coupling human and natural systems to find a balanced way to integrate the use of fire into landscapes, and to reinforce the need for consultation with and within communities. In broad terms, FST aims to bring together facets of IFM and community engagement.

FST is defined as "a territory with a shared governance model, in which empowered communities with high levels of knowledge and skills are able to decide and manage wildfire risk to keep it very low, through economic and social activities that not only can contain (in the end eliminate) wildfire hazard but promote the benefits of fire use" (Leone et al. 2020). FST offers an encompassing approach that includes organizational, ecological and social components. However, its use may create concern within communities that do not (or may not be

able to achieve) high levels of knowledge or skill in fire management decision making, or that may not consider the elimination of fire to be an appropriate end outcome.

The FST construct is certainly comprehensive. However, bringing together so many moving pieces, driving forces, operational principles and targets for efficiency and economic effectiveness (Tedim et al. 2016) makes it difficult to apply in field-level programmes. Also, its foundational concepts and approach are focused on addressing extreme wildfire events, as defined by Tedim et al. (2018), and thus would need to be adjusted to be implemented in landscapes that do not face events of such magnitude, intensity or complexity. Further consideration and analysis of FST within tropical landscapes is needed to better understand its potential areas of utility, and where it may be applicable.

The people and organizations to be involved — the "who"

The interactions between landscapes, people and fire are clear. Furthermore, in the same way that landscapes are not homogenous, neither are the people living in them. Determining who should be involved in fire management must include not only who the managing authority is, but who is affected.

However, it has taken time to acknowledge this important aspect. At a community-based fire management conference in Thailand almost 25 years ago, some participants argued that communities had almost no role to play in managing forest fires, and were only causes of fires. Authors of a paper presented there (Jackson and Moore 1998) also discovered that relevant, high-quality information on community involvement in fire management was difficult to find. In addition, early IFM constructs did not articulate the "who" facet or how to engage with people. The more recent concept of FST is beginning to involve these elements through its combined "human/natural system" approach, but this has yet to be applied in the field.

There are three aspects of "who" — people, institutions and communities — and various ways to engage them. Within these groups are different motives that drive their behaviour.

People

Engagement processes with people living in vulnerable conditions are significantly different from those for people who are more secure. So as part of the problem analysis (review) stage at the beginning of a wildfire programme, the analysis of the people within a landscape must include a consideration and understanding of differences in wealth, health and education, all of which could affect engagement methods.

Institutions

The institutions that undertake fire management are as varied as the landscapes themselves, within three primary types:

- formal organizations and settings: governments and regulatory bodies working on behalf of a jurisdiction, such as a district, province, conservation area or forest reserve;
- semi-formal organizations and settings: private companies on private land (which may or may not be regulated), or NGOs/conservation groups working on private lands or public conservation land; and
- informal organizations and settings: individuals, community or volunteer groups, whose activities may extend to areas beyond their home jurisdiction.

Defining the characteristics and drivers of each of these types of institutions is complex, but three aspects are notable. First, whether people are managing fire inclusively with wider society or exclusively — not all landscapes can be managed one way or the other, however, and the distinction may not be important. Second, accepting that politics and governance are not the same — governance is a non-ideologically-driven process that aims to improve the health, wealth and well-being of all people and the landscapes they live in; politics is an ideological approach that favours only some people. Third, the balance of technologically-driven or traditional techniques — a need for both is likely, and it may include prescribed fire skills from the past that have been lost.

Communities

Characterizing communities allows for a better understanding of how fire management concepts and practices may be differently treated by different members:

- communities that are dominantly agrarian or forest-oriented, or those that have livelihoods not specifically connected to the land;
- whether communities have secure land tenure, a key factor being not just the type of tenure, but whether people feel secure with the arrangements and their rights — an informal traditional tenure system may be stronger than formal tenure, which

Fires lit by the community, that are intended to be beneficial, but that may also increase risks to health. Photo: Pake Imam

can removed by an authoritarian government at any time; and

- community resilience and vulnerability, which are two sides of the same coin — the ability of a community to resist the negative impacts of landscape-scale wildfires, its reliance on landscape assets for livelihoods, and its ability to recover from wildfires that negatively affect those assets.

Community-based fire management

CBFiM is sometimes misunderstood, often thought to be similar to integrated fire management (IFM). IFM is predominantly an organizational construct and process for "how" to manage fire, whereas CBFiM is focused on "who" undertakes activities, not the activities themselves. It is useful to separate these aspects in order to better understand fire management. There is no clear separation of these notions in the literature, but understanding them is the intent of this article.

CBFiM as an engagement process originated in 1998 at an international community forestry workshop in Thailand. The Regional Community Forestry Training Center (RECOFTC) brought together experts to discuss how to more widely engage with communities in tropical countries, using tools, techniques and practices similar to those then in use in community forestry. It was at this workshop that Jackson and Moore (1998) noted the lack of information on, or belief in, community involvement in fire management. Several years later, in 2002, RECOFTC organized the first international workshop on community-based fire management, to build on the understanding of CBFiM through case studies from Africa, Latin America, Europe and Asia. CBFiM was then defined as "a type of forest management in which a locally-resident community (with or without the collaboration of other stakeholders) has substantial involvement in deciding the objectives and practices involved in preventing, controlling or utilising fires" (Ganz et al. 2003).

As noted, there were some early misconceptions that CBFiM was an organizational construct, but in practice it is a concept of how to include people; i.e., "who" should be engaged in managing fires. The concepts of CBFiM are focused on the people who live in and derive their livelihoods in the same landscape. The concepts also address people who are more vulnerable to negative fire impacts and who may face food insecurity after large fires. The growth and use of CBFiM has a strong link to tropical, agrarian and developing countries, and the approach is clearly a useful and important component in engaging with communities. Initiating CBFiM in landscapes, creating the foundation for inclusion, and then adding other approaches is a path to broader engagement, increased chances of success and more positive outcomes.

Indigenous fire management

The histories of indigenous and traditional cultures include the loss of many applications of fire. In some places the indigenous use of fire continues, but is often changing due to increased populations and changing

land dynamics. Engaging in indigenous fire management requires engaging with people, and understanding the techniques they apply in using fire in a contextually appropriate way. What is apparent for indigenous fire applications is the limited literature on engagement processes and possible ways to re-establish these practices within landscapes. Discussions of indigenous fire practices, such as the fire sticks forum in Australia and similar initiatives in the Americas, are enlightening for those open to these practices, but are confronting for those who are not yet prepared for the change.

What is clear in the context of increasing global wildfires is articulated by Pyne (2021) in his third paradox. If people reduce the consumption of fossil fuels and move to a low-carbon economy, they must simultaneously reintroduce fire to fire-tolerant and fire interdependent landscapes. The wildfire management community needs to actively consider the urgent need to reintroduce traditional and indigenous fire practices across large swaths of the world. This requires considerable added work and understanding to avoid further extreme wildfire events, which will occur if the ecological context is not considered.

Living with fire

The concept of living with fire is a recent, people-centric, cross-disciplinary approach. People who live in areas where extreme and overwhelming wildfires occur may not know that the landscapes that they live in have been changing as a result of a focus on fire suppression and on reduced use or prohibition of prescribed fire. Conversations must focus on living with fire as part of a process of re-education.

The need for inter-disciplinary, cross-sector and social-diversity approaches to understanding and dealing with fire management issues in complex situations has now emerged (Stoof and Kettridge 2022). These approaches examine "who" should be engaged during the design and development of fire management efforts, and includes conversations with people who are not strongly connected to their surrounding landscape; i.e., who do not create their livelihood from the landscape. Living with fire thus reinforces the need to analyze both what the fire problem is and who will participate in managing it. The concept requires people with a diversity of skills beyond wildfire management.

It focuses on the appropriate use of fire within communities and landscapes to manage risks and hazards from extreme wildfires, or from the lack of prescribed fire. It respects gender diversity in thinking and management, and incorporates inter-disciplinary approaches to complex situations surrounding fire management. Thus, living with fire is not a management construct, but an inclusive approach with great potential for successfully engaging people. See Figure 5.

Figure 5: Visualization of living with fire. Source: Stoof and Kettridge (2022)

Conclusions

This article reviews how historical landscape contexts have influenced fire management, and the reasons that circumstances are different today. It reviews how institutions are organized and how people are engaged, both within institutions and within communities. There is a clear need to look at each situation carefully before making decisions on landscapes and people and on what is right to implement at any one location and point in time.

The "how" section presents a working supposition that to better manage fire situations anywhere in the world, two steps are required. First: appreciate the landscape context and history, including: (i) climate, vegetation and fire ecology, (ii) socioeconomic, governance, political and human thinking, and (iii) fire use (indigenous or prescribed). Second: determine what the fire problem is, not just superficially, but by fully appreciating the underlying causes, components, drivers and related issues. This will highlight activities that can be conducted in a harmonized way in landscapes affected by fire.

The comparison of organizational structures for fire management plans and taking action in the field suggests a deeper consideration of IFM as the foundational construct, while integrating more community engagement approaches. IFM offer the greatest opportunity in a practical and coherent manner using the 5 Rs: review, risk reduction, readiness, response and recovery.

Regarding the "who," methods of engagement require thoughtful consideration. CBFiM and some indigenous fire engagement concepts are appropriate for communities who depend on landscapes for their livelihoods and can be well served by using these concepts as the basis of activities. However, urban edge and peri-urban communities in fire-prone landscapes may not be well served by CBFiM techniques, and the living-with-fire approach may be more suitable for them.

This review proposes three fundamental requirements for improved fire management.

1. Evaluate the natural and ecological aspects of fire in the landscape. What is the vegetation, climate and fire ecology (fire tolerant, fire sensitive, fire interdependent)? What is the socioeconomic, political and governance context? Do existing management agencies use fire appropriately, and does that fire use align with the landscape's natural fire ecology?
2. Look at the institutions in charge of fire management, for prescribed fires or wildfires. Do they assess the natural state of vegetation, climate, fire ecology and use of fire (or not) within a landscape? Are they capable of meeting the needs of the landscape, or are they single-minded and less adaptable in their approach?
3. Work with communities, listen to them and understand how they interact within the landscape before developing engagement methods. How much does a community depend on a landscape for its livelihood, or do people only reside there? Is there security of tenure? What is the relative wealth, health and education of the people who live and work in the landscape?

The simplicity of a proposition that considers just three areas of understanding before making fire management decisions gives a false impression, however. The reality is of course much more complex, with a variety in the mix of people, institutions, politics and landscapes involved. Nonetheless, a generic structure for analysis is proposed (Figure 6), although its complexity is likely to confound or complicate the identification of the balanced pathways needed to move forward.

It is clear that large parts of the world remain in the grip of the fire suppression mindset, and must reconsider the folly of that approach in the face of recurring extreme wildfire events, human suffering and lives lost. Land managers, conservation managers, farmers and communities work on lifelong projects with long-term goals. Pressures from the media and politics, however, have short perspectives and timeframes that influence the direction of appropriate fire management. Finding the right balance and techniques requires people to take the time to look carefully at the situation they face and to think through the steps outlined.

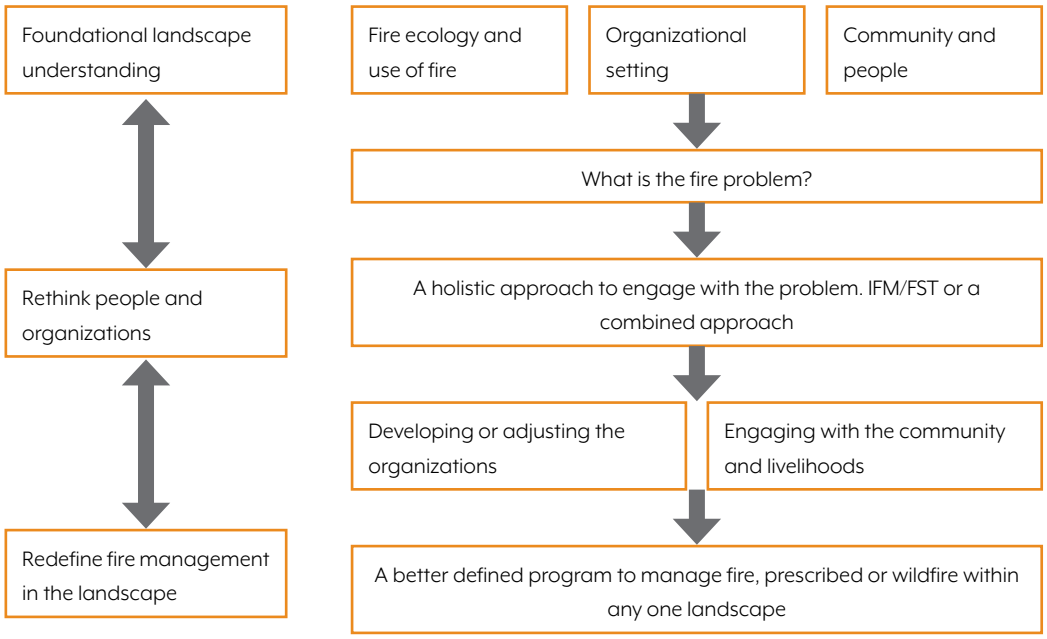

Figure 6: A schematic for fire management analysis

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1.3

Prescribed burning of understory vegetation and accumulated debris in a pine plantation. Photo: GFMC

Integrated fire management in tropical forests and open landscapes

Johann Georg Goldammer

"Safe fire management practices are fundamental, but to be truly effective they must be ecosystem-based, be applied with community cooperation, and follow national guidelines."

Introduction

Humans have used fire over millennia for sustainable cultivation and for maintaining tropical forest and open savanna landscapes, but in recent decades, fire has been excessively applied for land conversion, becoming an omnipresent agent in the degradation and destruction of native vegetation. Wildfires across the globe affect up to 600 million hectares annually; savanna ecosystems in Africa and South America account for more than half of all burned areas. Understanding fire ecology and fire use in tropical vegetation types demonstrates, however, that the effects of fire — unwanted and adverse impacts vs. ecologically and economically benign effects — are so varied as to make generic fire management advice impossible.

Land managers face the challenge of carefully investigating the specific real and potential roles of fire in their areas of responsibility or jurisdiction.

This is required in order to assess the extent to which fire exclusion or fire use is compatible with other management and conservation objectives, and to incorporate this knowledge in an integrated fire management (IFM) system. See Box 1.

This article discusses fire management options and practices for fuel management, fire suppression and prescribed burning. These must involve community cooperation and be implemented under national fire management policies and planning.

Box 1. Integrated fire management

The concept of integrated fire management (IFM) was introduced in the early 1990s. Initially it focused on forests, defined as a "*Designation of fire management systems which include one or both of the following concepts of integration: (1) Integration of prescribed natural or human-caused wildfires and/or planned application of fire in forestry and other land-use systems in accordance with the objectives of prescribed burning; (2) Integration of the activities and the use of the capabilities of the rural populations (communities, individual land users) to meet the overall objectives of land management, vegetation (forest) protection, and smoke management (community-based fire management).*" (GFMC 2017c).

The concept of integration addresses two dimensions: (i) ecosystem-based components and derived fire management objectives; and (ii) cultural and socioeconomic dimensions of fire management, as encompassed in community-based fire management, or CBFiM (GFMC 2017a).

Introduction of the IFM concept coincided with the first attempts to replace fire exclusion policies by applying IFM principles; e.g., Indonesia in 1991 (Goldammer 1993b), Sudan in 1991 (Bayoumi 2001), Namibia in 1997 (Goldammer 2001; Kojwang 2001), and Ethiopia in 2000 (MoA 2000). Since then, the concepts of IFM and CBFiM have evolved, and building on these, fire management guidelines for comprehensive approaches have been developed (ITTO 1997; Goldammer and de Ronde 2004; FAO 2006). See the GFMC online repository (GFMC 2017d) for these, and for guidance, principles and strategic actions not addressed in this article.

Fire management options – basic considerations

Different tropical fire regimes reveal the functional roles of fire in a range of ecosystems, with variable adaptations from fire dependence to fire intolerance. In response, fire management planning must have a solid basis, giving priority to the most vulnerable ecosystems. There are three basic options: fire exclusion; no fire management; and integrated fire management. In effect, integrated fire management embraces all possible treatments – fire exclusion, integration of uncontrolled but tolerable or desired wildfires, and application of prescribed fire. The ecological and economic implications of each treatment are summarized in Table 1.

Fire exclusion

Equatorial rainforests are extremely sensitive to fire and require strict exclusion of fire in order to not jeopardize conservation or management objectives. This is also the case in forest plantations stocked by fire-sensitive trees, and in tropical peat-swamp forests. In these cases, fire management requires strict fire prevention and control and an efficient fire protection organization.

No fire management

Vast areas of tropical and subtropical open deciduous and semi-deciduous forests, grass, bush and tree savannas burn annually or in short-return intervals. Burning patterns (timing, frequency) may align with traditional land treatment practices, or may be subject to chance (e.g., caused by lightning), and there may be no alternative but to let fires burn due to a lack of fire management capability, access, infrastructure and resources for suppression. Uncontrolled fire regimes in fire-climax savanna and forest landscapes may be tolerable, however, if there is no additional degradation (e.g., from overgrazing).

Integrated fire management

The implementation of integrated fire management, with the active participation of local communities, can increase productivity and sustainability. Implementing IFM principles can, for example, lead to increased tree cover in savanna landscapes or on degraded forest land. Applying IFM, however, requires a thorough understanding of the impacts of fire in specific tropical vegetation types, and the capability to actively manage all fire situations. This includes preventing and suppressing all undesirable fires, taking advantage of the benign effects of fire to achieve management goals

Table 1. Ecological, economic and management aspects of integrated fire management treatments in various tropical forest, forest sub-types and savannas

	Ecological and economic aspects of fire	Deciduous broadleaved forests (e.g., *Tectona, Shorea*)	Coniferous forests (e.g., *Pinus* spp.)	Industrial plantations (e.g., *Pinus* and *Eucalyptus*)	Silvopastoral systems (e.g., open pine forests with grazing)	Grass savannas (e.g., extensively grazed lands)
Fire exclusion	Ecological impacts	High diversity of species, habitats and niches High water-retaining and soil-protection capability	Replacement of coniferous species by less fire-tolerant broadleaved species Pines only on dry shallow and disturbed sites Overall increase in species diversity High water-retaining and soil-protection capability	High risk of uncontrolled high-intensity stand-replacement wildfires due to fuel accumulation	Undesirable increase in species not suitable for grazing purposes Replacement of grass layer by succession	Progressive successional development towards brush/tree savannas or forest Promotion of less fire-tolerant species
	Economic and management implications	Economic timber production difficult because of high species diversity Increase in non-timber forest products	Economic timber production difficult because of high species diversity	Timber production feasible Extreme high risk of destruction of plantations by wildfire	Only possible if intensively grazed and mechanically cleared	Not feasible
Uncontrolled wildfires	Ecological impacts	Selection of fire-resistant/tolerant tree species Opening of forest formation	Retreat of fire-sensitive species and favouring of fire-resistant pines Opening of forests Stand-replacement fires Forest degradation	Stand-replacement fires	Uncontrolled selective fire pressure Maintenance of openness	Maintenance of a wildfire climax Uncontrolled selection of fire-adapted plants
	Economic and management implications	Species composition and relevant management and marketing opportunities get out of control	Tendency to degradation and loss of productivity	Management objectives jeopardized if no efficient fire prevention and control system available	Possible long-term degradation and loss of productivity	Productivity depends on savanna type and on degradation factors involved
Prescribed fire (integrated fire management)	Ecological impacts	Controlled selection of tree species Advantageous for stimulation and harvest of selected non-timber forest products	Controlled favouring of desired fire-tolerant species Reduction of stand-replacement fire risk	Maintenance of desired plantation monocultures Reduction of stand-replacement fire risk Increased vitality	Controlled promotion (stimulation) of desired tree and fodder plant species	Controlled promotion of desirable grass/herb layer and tree/shrub regeneration
	Economic and management implications	An integrated fire management system requires availability of relevant ecological background knowledge, trained personnel, and the infrastructure and facilities to prevent and control undesired wildfires and to conduct safe prescribed burning operations				

Adapted from Goldammer (1993a)

Sheep grazing under high pruned *Pinus radiata* in New Zealand in a silvopastoral system that acts as a fuelbreak. Photo: GFMC

by prescribed burning, and defining and controlling the threshold between desired and undesired effects of uncontrolled natural and human-caused fires. The effects of fire on ecosystem properties and stability, including carbon sequestration capacity, tend to vary depending on seasonality. For instance, fires burning at the peak or end of the dry season are generally more severe and destructive due to extreme fire weather and accumulated fuels, whereas fires in the early dry season tend to be less intense and severe and cause less damage.

Fuel management

Preventing wildfires in forests and open landscapes and within or at the interface of residential areas includes a range of measures for reducing the amount of combustible materials (fuels) that may ignite and contribute to the spread, intensity and severity of a wildfire. The most important fuels in forests are surface fuels (grasses, herbs, shrubs) that allow horizontal fire spread, and understorey trees and "aerial fuels" (dead branches and hanging foliage) that have the potential to become "ladder fuels," which allows the vertical development of a surface fire into a crown fire. The treatment of these fuels can be practised inside the forest stands to be protected, or in buffer zones (wildfire protection corridors / fuelbreaks).

Firebreaks

These are strips several to many metres wide, where all combustibles are removed and the soil is exposed. The width varies with fuel loads and the risk of fire jumping over the firebreak, which can happen even with those 25 m or wider. Creating and maintaining such large and unproductive strips of land is costly, and firebreaks on steep slopes are also susceptible to erosion.

Agricultural fuelbreaks

The concept of a fuelbreak is different. These are generally wide (up to several hundred metres), and flammable vegetation is modified so that fires burning into them can be more readily controlled. In the tropics, it has been successfully demonstrated that fuelbreaks can be maintained economically by having them integrate agricultural or agrosilvopastoral land uses that involve cultivation and the removal of aboveground biomass. The species to be planted depend on the site and climate conditions, but some basic principles should be observed.

Fuelbreak design must consider the need for growing crops, and flammable residues must be removed prior to periods of high fire danger. Growing millet *(Pennisetum glaucum*) on fuelbreak strips is an example. A staple food in much of Africa and Asia, the grain is usually harvested at the beginning of the dry season, and the highly flammable stems and leaves are left in the fields until the end of the dry season. In fuelbreaks, farmers must remove these crop residues before the start of the fire season. Other species suitable for agricultural fuelbreaks are creeping plants such as beans or groundnuts, which do not carry surface fire due to more frequent tillage and their low and spaced growth.

Community members with personal protective equipment and backpack pumps fighting a surface fire, Terai, Nepal. Photo: Sundar Sharma

Pastoral and silvopastoral fuelbreaks

Integration of grazing is another method of reducing the flammability of surface fuels on treeless strips (pastoral fuelbreaks) or on silvopastoral or shaded fuelbreaks with grazing under widely spaced trees. Grass could be natural or seeded, and prescribed grazing (Goldammer 1988) and browsing of brush and seedlings reduces the total fuel load. If grazing/browsing is selective, leaving certain species unaffected, cutting or prescribed burning will be necessary to reduce the fuel load. Pastoral fuelbreaks may include firebreaks such as small strips along each side; these are mandatory if prescribed fire is applied for maintenance. Shaded fuelbreaks are managed for livestock and timber, and possibly other tree products. Trees offer shade and shelter, improving animal welfare and performance. High pruning of the trees that removes fuel is necessary, and also increases the light available for grass growth and improves timber quality (and value).

Fuelbreaks without other land use

All combustible material must be cut by hand or machine and burned, removed or chipped and left on site. A compact layer of chipped fuels is generally less flammable than other fuels and any surface fire is easy to control. The use of prescribed fire on fuelbreaks follows the general concepts described below.

Fuel management inside forests

The choice of fuel reduction methods requires careful economic planning, as pruning, thinning and removal of understorey vegetation and other surface fuels are labour intensive. Costs can be reduced if the material is used by local people or sold; e.g., for fuelwood or woodchips. Fuels inside forest or plantations adapted to low-intensity surface fires can also be treated by prescribed fire (under-canopy = underburning) to reduce fuel accumulation (see below).

Fire suppression

Most advanced technologies for wildfire suppression have been developed in industrialized nations, and are less commonly used in tropical countries due to a lack of infrastructure, trained personnel and financial resources. It has been recognized, however, that most fire situations throughout the world can be successfully managed by experienced professional and volunteer firefighters, or by adequately trained community members. The success of ground crews depends on the availability of appropriate hand tools and personal protective equipment, and the provision of basic training in fire suppression and firefighter safety.

These are the most important techniques and most appropriate hand tools for each type of fire suppression:

1. Extinguishing surface fires by dowsing or beating, using fire swatters and backpack pumps (collapsible bags holding around 20 litres of

water, with a hand pump and nozzle, the simplest and most efficient, flexible and economical of all dowsing options).

2. Creating firelines or control lines (firebreaks made after a fire has started, to prevent its spread), using machetes, mattocks and similar tools for cutting and clearing vegetation and exposing the soil.
3. Setting tactical fires (also called suppression fires, backfires or counter fires, using drip torches or other means of ignition), which are very successful when applied by experienced fire teams. Many rural people in the tropics also have a lot of knowledge on how to use backfires, but these fires can be dangerous when they are started by people with no experience.

Fire safety training, including the use of backfires and prescribed burning techniques, must be mandatory for communities involved in any fire management activities.

Extensive information on fire suppression techniques is available from handbooks (e.g., de Ronde et al. 1990; Goldammer and de Ronde 2004), and from online resources for training firefighters. For example, the EuroFire Competency Standards and Training Materials, developed by the Global Fire Monitoring Center (GFMC) for training European fire and rescue service personnel, is now available in 22 languages (GFMC 2017b). It includes examples of and illustrations for the safe use of prescribed burning and backfires (Figure 1).

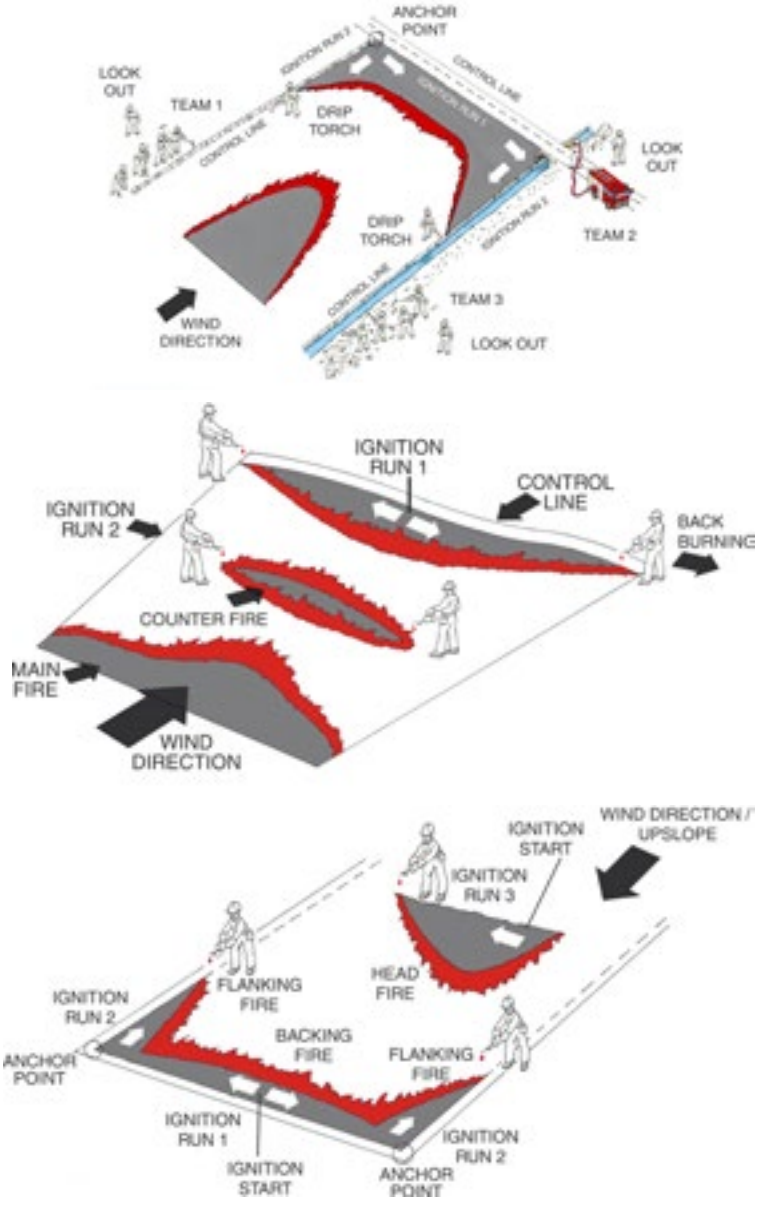

Figure 1. Examples of safe backfiring. Source: GFMC 2017b

Prescribed burning

Prescribed burning is the controlled use of fire to vegetation fuels under specific environmental conditions in order to create a fire of the desired intensity and rate of spread to meet a range of management objectives. It is also necessary where forests would otherwise be endangered by total fire exclusion, or by uncontrolled fires. In the tropics, prescribed burning is often called "early burning," and fires are usually set in the early dry season to prevent the risk of their becoming uncontrolled when vegetation is even drier.

Extensive expertise is available on prescribed burning in pine plantations (e.g., de Ronde et al. 1990) to meet various management objectives (Table 2). The main goal is to use low-intensity underburning of forests or plantations to reduce the accumulation of surface fuels, which greatly reduces the risk of damaging, high-intensity wildfires. Such fuel-reduction burns also speed up the recycling of nutrients from woody matter that would otherwise be slow to decompose. The interval between successive burns depends on the tree and understorey species, fuel accumulation rates, values at risk, and wildfire risk.

Table 2. Objectives for using prescribed fire in pine plantations

Objective	Target	Desired effects	Undesired effects or potential hazards	Possible substitution
Wildfire hazard reduction	Thinning or post-harvest slash, forest floor (raw humus), aerial fuels, rank understorey	Reduce potential wildfire intensity and severity, remove surface and ladder fuels	Stand/tree damage (crown, bole or roots)	Partial removal (mechanical treatment by hand, shredding, piling and burning outside of stand, pruning)
Site preparation for natural regeneration or planting	Forest floor, post-harvest slash, undesired vegetation	Expose mineral soil (improve germination), increase seed fall	Encroachment, sprouting, or germination of undesired plants	Partial removal (herbicides to kill undesired vegetation)
Improve accessibility	Thinning of post-harvest slash, rank understorey	Improve access for silvicultural operations, aesthetics (recreation)	Reduction of understorey stature	Partial removal (herbicides to kill undesired understorey)
Increase growth/yield	Raw humus layer (forest floor), understorey plants	Enhance nutrient availability; reduce competition for moisture, sun and nutrients	Loss of nutrients (leaching), erosion	Fertilization and herbicides
Alter plant species composition	Weeds and other undesirable vegetation	Promote desired species	Increase in weed germination and production of undesirable seeds	Herbicides
Pest management	Pests and diseases and their habitats	Eliminate spores, eggs, individuals and breeding material	Fire-induced tree stress, increased susceptibility to secondary pests	Pesticides
Silvopastoral land use	Slash; forest floor; mature, unpalatable growth; competing vegetation	Create/improve conditions for desired ground cover	Browsing or peeling of sensitive trees may jeopardize the concept	Mechanical removal of dead fuels and vegetation
Improve fire protection	Surrounding buffer zone, fuelbreaks and firebreaks	Reduce spread and intensity of wildfires (outside of stands)	Residents may miss shade and aesthetic values of trees nearby their houses	none

Adapted from Goldammer (1993a)

The safest technique for underburning plantations is using a fire that burns against the wind (backing fire), started along a downwind baseline such as a road or a plough line. The wind (at preferred speeds of 2–5 km/h) keeps flames bent over and cools the air above the flaming front, thus reducing the risks of crown scorch or crown fire. Relative humidity strongly influences the moisture content of fine fuels, which is the most important parameter affecting prescribed fire behaviour. For a successful burn, relative humidity should be 30–50% and the moisture content of the litter layer should be greater than 30–35% (de Ronde et al. 1990). Most of the experience in prescribed underburning is from pine and eucalyptus forests and plantations, but much of this expertise can be adapted to tropical deciduous and semi-deciduous forests. Extensive knowledge is also available in the use of prescribed fire to maintain or restore open savanna "fire ecosystems."

(a) Starting a prescribed fire in a Kenyan tree-grass savanna using a traditional ignition device; (b) Aerial view of the resulting fire, with roads as fire-breaks and an aircraft for safety patrols; (c) Equipped community members setting a backfire in a sal (*Shorea robusta*) forest, Nepal; (d) Prescribed underburning in a *Pinus taeda* plantation, Paraná, Brazil, after aerial fuels (dead branches, hanging needles) have been removed to a height of ca. 2 m. Photos: GFMC (a, b, d); Sundar Sharma (c)

Burning logging debris and managing smoke

Another application of prescribed fire in the tropics is for burning logging debris on forest land, before sowing crops or conversion to other land uses. This requires less experience as there are no standing trees that need to be protected, but the amount of wood to be burned is considerably higher than the biomass combusted by underburning. Precautions are needed to avoid fires escaping into other areas, and to prevent hazardous near-ground concentrations of smoke. Both risks can be controlled by using appropriate burning techniques and by observing the factors that influence fire behaviour, such as the spatial arrangement of fuels, fuel moisture, fire weather, etc.

There are two basic burning patterns for logging debris: broadcast burning (use of the ring fire technique, also called centre or circular firing), and pile or windrow burning. The ring fire technique is preferred as it reduces near-surface air pollution. The aim in piling logging

debris before burning is to prolong fire residence time to ensure that large logs burn thoroughly. The use of heavy machinery, however, tends to add large amounts of topsoil to the piles or windrows. This makes the interior moist so that fuels hardly dry at all. Consequently, oxygen for complete combustion is lacking, resulting in a fire that can smoulder for weeks and that reduces near-ground air quality. In contrast, convection from the ring fire technique produces smoke columns into the atmosphere, but attention must be given to the risk of creating spot fires in adjacent fire-prone area from burning or from smoldering material that rises with the smoke.

Escaping fires can be prevented by constructing firebreaks around the area to be burned beforehand, and by using ignition patterns such as the ring fire technique that drive the fire into the centre of the burn area. The ring fire technique is useful in clearcut areas where a hot fire is desired in order to burn logging debris and unwanted vegetation as much as possible prior to planting. As with the backfire technique, the downwind control line is the first to be ignited. Once the baseline is secured, the perimeter is ignited so the flame fronts all converge toward the centre. Often, one or more "dot fires" are also ignited in the centre and allowed to develop before the perimeter of the burning block is ignited, to create in-drafts that help pull the outer circle of fire toward the centre, thereby reducing the threat of the fire escaping or of heat damage to adjacent areas.

Prescribed burning plans

Although detailed burning methods for tropical forests are not yet available, many principles and considerations of prescribed burning in pine and eucalyptus plantations can be used in planning. A successful prescribed fire is one that is executed safely, is confined to the planned area, burns with the desired intensity, accomplishes the prescribed treatment, and is compatible with resource management objectives. Prescribed fire planning should be based on the following six factors (de Ronde et al. 1990):

1. physical and biological characteristics of the site to be treated;
2. land and resource management objectives for the site to be treated;
3. known relationships between pre-burn environmental factors, expected fire behaviour, and foreseeable fire effects;
4. the existing art and science of applying fire to a site;
5. previous experience from similar treatments on similar sites; and
6. smoke impacts from a health and safety standpoint.

Prerequisite conditions

Safe fire management practices are fundamental, and to be truly effective they must be applied with community cooperation and follow national guidelines.

Effective community cooperation

Surveys of fire causes reveal that the most important reason for the careless use of fire is a lack of awareness of the economic and ecological benefits of forests and forest protection. It is also recognized that conflicts between forestry and agricultural land users can provoke careless and intentional setting of forest fires.

Tropical forest fire managers rely heavily on a positive relationship between the forests they manage and the people living and working in rural areas. Mutual confidence and public support are promoted through participatory approaches, and by employing local people, especially in fire prevention and wildfire hazard reduction measures such as establishing and maintaining firebreaks. Integrating agriculture and grazing into fuelbreaks (as described above) creates additional confidence and local participation through cost-free leasing of fuelbreak land to local farmers and livestock owners.

Other measures that stimulate cooperation in fire prevention are bonus incentives that provide funding for communities if no fire occurs on specific land during a specific time. These must be accompanied by targeted public information through the media, social media, schools, churches, etc. In addition, since the use of fire remains vital in many tropical land-use systems, fire management extension services must be established to provide information and training to communities on safe and controllable burning techniques that keep fires within intended areas and reduce the risk of accidents.

The concepts of participatory, community-based fire management are increasingly being applied in many countries. Background information, case studies and outreach materials can be found on the GFMC web site (GFMC 2017a), including the easy-to-read Guidelines on defence of villages, farms and other rural assets against wildfires: guidelines for rural populations, local communities and municipality leaders (Goldammer et al. 2013).

Fire prevention planning in a community in Mozambique. Photo: GFMC

National fire management policies and implementation plans

National fire management policies are an essential foundation for informed and coordinated fire management activities. These policies must address all vegetation types: natural vegetation (including forests and non-forest ecosystems), plantation forests, protected areas, wetlands and peatlands, agricultural land, pastureland (rangeland), abandoned (formerly cultivated) land, and vegetated land contaminated by industrial or chemical waste, land mines or unexploded ordnance.

To develop truly cross-sectoral, consent-based fire management policies, legislation, regulations and implementation strategies and plans, some countries have established national inter-agency fire management centres or advisory boards. To be effective, these must involve line ministries, other public institutions, and civil society organizations, including local communities, agricultural associations, land and forest owners, NGOs and volunteer groups. Relevant ministries and government agencies are those responsible for forestry, environment (for all issues potentially affected by fire, including climate change), agriculture (regarding fire use in farmland and rangeland), public health (to protect people from the adverse effects of smoke pollution), emergency planning (civil protection, fire and rescue services), foreign affairs (for trans-boundary fires, pollution and international protocols), and defence (for assistance in wildfire emergencies).

For policies, strategic planning and decision making to be effective, some key principles should be considered:

- **Evidence**: Use sound interdisciplinary scientific knowledge and consider technological capabilities and innovation, such the revival of traditional, benign land-use practices.
- **Inclusion**: Address fire problems at the landscape level by including and integrating all relevant institutional mandates and the contributions from civil society.
- **Coherence**: Harmonize the fire management mandates and activities of government institutions and other stakeholders with cross-sectoral national policies and implementation plans.
- **Cohesiveness**: Consider national fire management plans obligatory for individual institutional and sectoral planning and implementation.
- **Coordination**: Continuously monitor the implementation of actions under national fire management plans in a highly coordinated manner and make the results publicly available.

Themes to be addressed in national policies should include, but not limited to, the following.

- **Research, information and analysis**: Establish a national unit of competence in fire management to assist all participating agencies and other stakeholders in the joint implementation of policies; e.g., by creating a national fire management body or office.
- **Legal framework and institutional responsibility**: Review and update legislative and regulatory frameworks to define the responsibilities and obligations of government agencies and civil society (particularly local communities and individual land owners and land users) in fire management planning, capacity building, fire prevention, preparedness and response.
- **Reduction of fire hazard, risk and vulnerability, and prevention of fires**: Systematically implement technical fire prevention measures in forest, agricultural, pastoral and abandoned land. Prioritize public awareness of the negative consequences of fires and the need for active participation in fire prevention, notably by local communities in fire-prone regions in order to defend their assets against fires.
- **Preparedness (provisions to improve fire response and safety)**: Provide appropriate training for firefighters and other personnel from agencies responsible for forest fire suppression, including volunteers, to ensure their competency, efficiency and safety. Establish wildfire early-warning systems to provide and disseminate warnings of high fire danger and thus allow for preparedness and early alerts at local and national levels.
- **Response (wildfire suppression)**: Ensure that specialized forest fire suppression units and sub-units are available in areas of high fire risk and that they are appropriately equipped. Land management authorities (e.g., agencies responsible for forestry, protected areas and agricultural land) must provide budgets for training and equipping specialized fire management teams in areas of high fire risk.
- **Post-fire measures**: Reduce the threat and consequences of secondary wildfires effects, such as erosion, lack of regeneration potential, reduction of water-holding capacity, increase in surface runoff and risk of flash floods, mudslides, landslides and rock falls.
- **International cooperation in fire management**: Share knowledge of fire science and management, and actively participate in regional and global networks to ensure that countries take advantage of international state-of-the-art expertise.

Conclusions

Complex and ambiguous phenomena and problems are associated with fire use and wildfires affecting tropical forests, and other ecosystems and land-use systems. The socioeconomic and cultural conditions in tropical environments are decisive in shaping fire regimes. Managers of forests and other land resources throughout the tropics are facing tremendous pressures posed by humans, the climate crisis and fire.

This article provides a basis for understanding fire-induced processes, and for the need to develop adequate fire management concepts and implementation strategies, highlighting basic processes, phenomena and solutions. These are challenges for decision makers, while the complexity of interactions between land use and other human activities, tropical vegetation characteristics, climate and climate change may also mean that decision makers require expert assistance in capacity building for fire management at local and national levels.

In addition to publishing fire management guidelines and textbooks, the Global Wildland Fire Network is available to provide assistance, through 14 regional networks and eight regional fire management resource centres (GFMC 2017e). Four of these operate in the tropics: East Africa (based in Madagascar), West Africa (Ghana), Southeast Asia (Indonesia), and South America (Brazil). In conjunction with the International Wildfire Preparedness Mechanism (IWPM), the centres facilitate exchange of knowledge and expertise in fire management, both within regions and globally (GFMC 2017e).

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Section 2

The Americas

Photo, previous page: Community firefighters in Ecuador. Photo: Amazonia sin Fuego programme

2.1

Traditional burning by the indigenous Pemón people in conucos (shifting cultivation areas). Photo: Ruth Salazar-Gascón

An intercultural vision for integrated fire management in Venezuela

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"Fire management planning and implementation must consider the benefits and learn from the indigenous use of controlled fire."

*Very sadly, Bernardo Ancidey passed away from Covid-19 prior to publication of this article. He will be greatly missed. Condolences to his family and friends.

Introduction

Climate change and governance conditions have made wildfires a critical issue that transcends academic and technical issues and enters socio-political arenas. In Latin America, indigenous peoples, peasant communities, peri-urban populations, firefighters, biodiversity and ecosystems are all vulnerable and threatened. This situation represents a paradox in Latin America, as fire has historically been an essential sustaining element in the survival and domestication of the territory, and in the cultural heritage of the original Amerindian peoples (Bilbao et al. 2019). However, changes in fire regimes introduced by European settlers, and policies of newly independent states, have made the situation worse (Box 1), leading to justified demands for a paradigm shift.

Fire control demands increased budgets and efforts, especially in conservation programmes (Mistry et al. 2016). However, policies that

exclude virtually all types of fire have had limited impact, and in fact, appear to increase the risk of large and severe wildfires. In Venezuela, for example, the Environmental Criminal Law enacted in 1992 and reformed in 2012 contains measures that prohibit fire and punish those who use fire in protected areas, and limit the management by or inclusion of traditional practices of local populations (Government of Venezuela 2012).

Given the scenarios that will likely lead to a continued increase in the size and severity of wildfires, programmes with a holistic vision are urgently required; they must be oriented to fire prevention rather than fire suppression. Furthermore, due to the role of fire in maintaining ecosystem diversity and function, and the richness of traditional fire-use practices by local populations, it is necessary to consider the socio-environmental aspects of fire, and to promote interaction and dialogue between a range of actors to establish more inclusive, intersectoral, participatory and intercultural governance.

This article describes the advances, challenges, limitations and progress in the development of a new paradigm of Integrated Fire Management (IFM) with an intercultural vision in Venezuela, from its beginnings in Canaima National Park to its later convergence with government actions and those of firefighters.

Box 1. Changing fire regimes in Latin America

The fire was a key element in early agriculture in the tropical forests of Latin America, mainly characterized by unfertile, low pH and weathered soils that are exposed to high temperatures and heavy rainfall. Unlike in temperate regions, nutrients are found in the vegetation rather than in the soil, and fire catalyzes the release of nutrients, making agriculture possible and facilitating regeneration after the end of the crop cycle. Indigenous peoples have also used fire for hunting and fishing, to induce the fruiting of wild plants, and to reduce fuel levels in savannas to prevent the spread of wildfires to adjacent forests. Fire also plays important roles in the cultural and religious dynamics of communities, being a central element around which ancestral traditions and cosmovision are maintained.

There is clear evidence of the sustainability of these Amerindian practices, which historically were compatible with the diversity and maintenance of forests, even in Amazon rainforests that have not evolved with a high exposure to fire (Piperno et al. 2019). Perhaps the greatest evidence of this coexistence is revealed in the extensive forest mass on the continent that was home to hundreds of thousands of indigenous peoples before the arrival of Europeans. However, pre-Columbian indigenous practices, maintained for millennia, suffered after European colonization, under the imposition of socioeconomic concepts of land use that were drastically opposed to those of the original inhabitants.

Large tracts of South America were transformed into agricultural and livestock production systems based on monocultures and pastures, following deforestation and the indiscriminate use of fire by the new settlers. Settlers disregarded indigenous practices, leading to a marked deterioration in natural and sociocultural systems. The most important change in fire regimes was the repeated setting of high-intensity wildfires at the end of the dry season in an attempt to eliminate native vegetation from the forests (Vieira et al. 2019). Thus, instead of fire management based on controlled burns used by the indigenous peoples, uncontrolled fire as wildfire was introduced. Consequently, this cultural and political approach to the use of fire, introduced by Europeans in the 1600s, produced a dramatic change in tropical American landscapes.

Faced with the increase in large forest fires and damage to vulnerable ecosystems, administrative and legal actions were undertaken by several governments in Latin America in the 1900s. These efforts created protected areas such as national parks, and “zero fire” (or “zero burning”) policies that focused on the exclusion and prohibition of fire and even criminalized those who used fire (Bilbao et al. 2010; Eloy et al. 2019).

Under a business-as-usual scenario, there is an increased likelihood of more frequent and severe wildfires, due to higher temperatures and droughts associated with climate change, altered fire regimes with accumulating combustible material under “zero fire” policies, changes in settlement patterns that lead to both land clearing and land abandonment, and changes in land use from local practices to agro-industrial exploitation. Expansion of the agricultural frontier in forested areas is of particular concern, with fires used as an economic and practical means of eliminating vegetation, alongside the absence of state protection of forests or lack of enforcement, and only an incipient interest in fire risk prevention and integrated fire management.

Canaima National Park

On the border between Venezuela and Brazil in the northern Amazon basin, the three-million-ha park is the third largest in Venezuela and the sixth largest in Latin America. Evergreen tropical rainforests cover 60% of the park, alternating with savannas and other ecosystems in a characteristic mosaic landscape (Figure 1). It is emblematic for conservation due to its high biodiversity and unique species, and was declared a UNESCO Natural World Heritage Site in 1994. The park also includes the headwaters of the dammed Caroní River, which provides 80% of the country's energy.

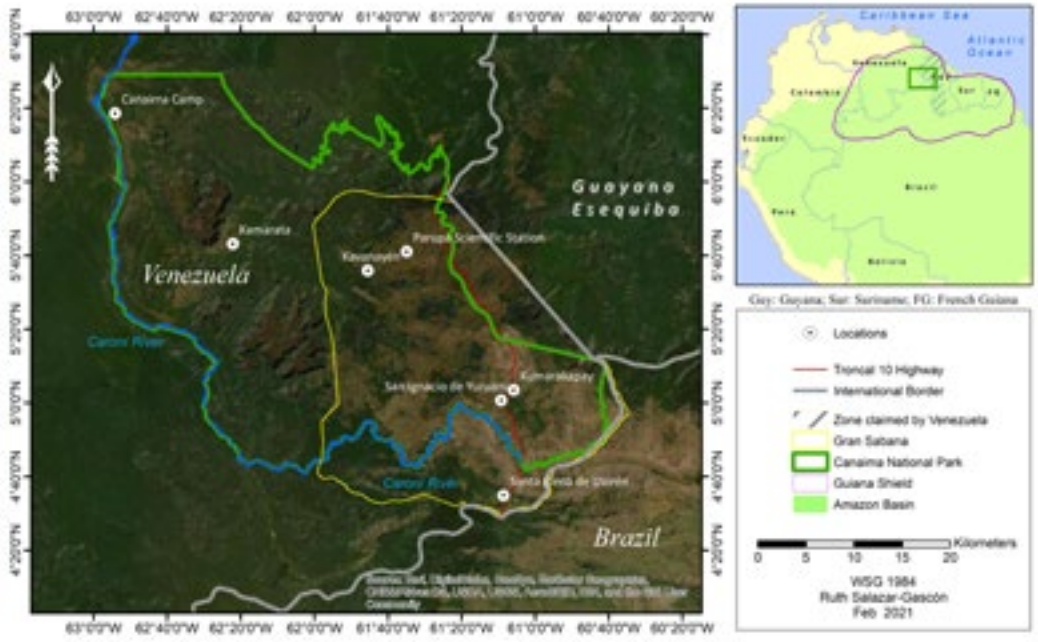
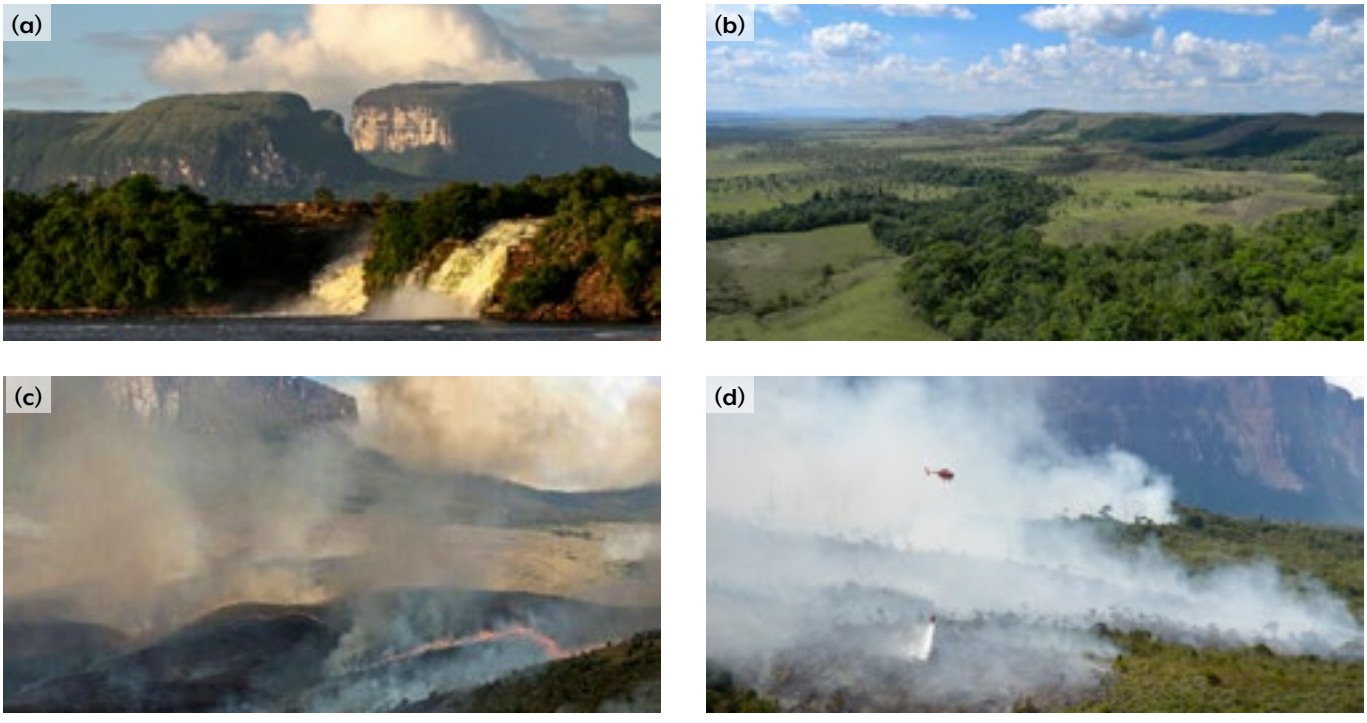


Figure 1. Location of Canaima National Park. Dark green indicates areas with forest cover, and light brown indicates savannas. Source: Ruth Salazar Gascón, published in Bilbao et al. (2021)



Diverse landscapes and vegetation in Canaima National Park threatened by high-intensity wildfires.
Photos: (a) Maiquel Torcatt, (b) Adriana Millán, (c) Humberto Chani, (d) PCIV-CORPOELEC

An experimental burn initiated by indigenous Pemón members of PCIV brigades. Photo: Bibiana Bilbao

The park is part of the ancestral territory of the Pemón people, the fourth largest indigenous group in the country, but there are also other interests in the park and its surroundings. These include the national hydroelectric company (CORPOELEC), the national park authority (INPARQUES), the national armed forces, and the local government, among others. These diverse actors have different and even conflicting interests, leading to a complex context. For example, biodiversity in the park is not only an aim of conservation, but also has cultural, spiritual and subsistence value for the Pemón.

Pemón communities use fire widely: for domestic purposes, in hunting to ambush prey and to stimulate production of tender grass shoots (which transform savannas into feeding and hunting grounds, and to make insects jump into the water and attract fish), for clearing roads, for protection against snakes and scorpions, and for communication with smoke signals. Fire provides an important link to the spiritual world, used in ceremonies and ritual practices to ward off evil spirits, in celebrations around bonfires, and for healing. Fire and its uses are strongly linked to education, transmission of knowledge, and maintenance of culture (Bilbao et al. 2019).

In farming, fire has an essential role in improving soil quality, allowing the planting of crops in small forest clearings (*conucos*) that are cultivated for two to three years, then left to regenerate for five to twenty years. Burning is carried out upwind (backfiring) in the early morning, while flammable material is damp to prevent the fire from spreading, and to allow a full day to contain and control the fire. Fire is also used to prevent savanna wildfires from spreading into the forests that are crucial to livelihoods.

Fire suppression policies in the park

In 1981, the national hydroelectric company and the *Corporación Venezolana de Guayana* began a vegetation fire control programme (PCIV) to protect and conserve the forests of the Caroní basin, including Canaima National Park. A fire exclusion policy was implemented, in response to the long history of forest fires, especially those of 1979 and 1980, which affected extensive areas of forest, scrubland and savanna, shocking the public and the media. The Carlos Todd Initial Attack Brigade also began its work at this time. It was responsible for preventing, detecting, investigating and fighting forest fires, including to minimize burning and ensure proper fire management by indigenous Pemón communities (Gómez et al. 2000; Millán 2015).

Despite enormous organizational efforts and huge investments in infrastructure, equipment, aircraft, and hiring and training of personnel, an average of only 13% of the 1,000–3,000 annually reported fires were effectively controlled. Also, according to some inhabitants and park officials, wildfires actually became larger and more difficult to control, in particularly in drought years. The programme also ignited a historical conflict with the Pemón, whom CORPOELEC called “burners” and the cause of the “fire problem” in the park as a result of their burning practices. However, the Pemón perceived that the conservation policies and programmes of the various public bodies in the park not only prohibited their traditional use of fire, but also extinguished their cultural values and their capacity for self-management in their ancestral territory (Bilbao et al. 2019).

Not all fires are wildfires

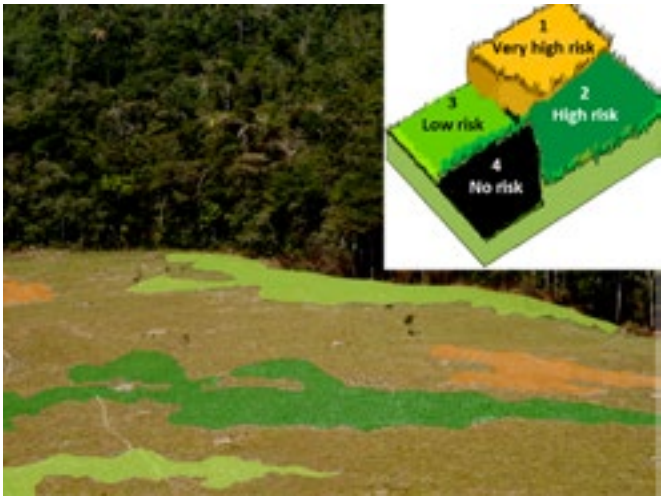
Although scientific articles supported fire suppression policies in the park, there were no studies that provided evidence of the direct impact of fire on vegetation and soil, the role of climatic variables and fuel material on fire behaviour, or effects on ecosystems. CORPOELEC requested support for a study to quantify these variables and reinforce their fire control and management practices. In 1999, a series of long-term fire experiments were initiated, led by researchers from Simón Bolívar University, to evaluate fire behaviour and its effects under different burning frequencies and treatments during the dry season. This formed part of the multidisciplinary project, Atmosphere-Biosphere Interactions in the Gran Sabana, Canaima National Park, financed by the Ministry of Science and Technology.

Participatory experimental burns were conducted in a savanna-forest gradient (where 70% of fires usually start), simulating indigenous practices. Members of the Pemón and PCIV-CORPOELEC fire brigades participated (Bilbao et al. 2010). The main results were these: fire can occur in a variety of climatic conditions and with different combustible materials; burns are highly variable in intensity and fire behaviour, but generally have low combustion efficiency; controlled burns are possible only every three to four years due to limited regeneration after burning; and savanna areas left for more than four years without burning have a biomass of >0.6 kg/m2 and a green/dry ratio >1 and so have a higher risk of high-intensity and uncontrollable wildfires.

These results indicated, contrary to general belief, that not all fires are wildfires. Burns showed different behaviour and rates of spread and fire intensity, and were affected by the interactions of environmental factors such as wind, temperature and humidity, and by vegetation characteristics defined by the accumulation and arrangement of biomass. None of the 31 experimental burns was the same, indicating the high diversity of fire types even in the same vegetation type. This also countered the myth that wildfire, when it occurs, is always catastrophic.

The results also showed that intentional burning of savanna vegetation at different times creates patches with different burning histories, forming a mosaic. Characterizing the ecological basis of what was termed the patch mosaic burning (PMB) technique was a significant result of the study. More important was the finding that this technique is used by the Pemón to make firebreaks to slow the advance of fire when entering a recently burned area; this prevents catastrophic wildfires in the forested areas that they depend on for hunting, shifting cultivation, fruit and wood gathering, etc.

Another revealing result was that prolonged exclusion of burning led to a significant accumulation of dry combustible material, leading to high-intensity fires. This proved that the fire exclusion policy in the park may have actually increased the fire problem, and suggested the need to shift from fire suppression to fire management. This shift would incorporate indigenous practices that manage fire in a way that favours a diversity of vegetation (pyrodiversity) and that reduces the spread of large fires (Bilbao et al. 2010).



Areas with different risks of fire (according to the time since the previous burn), resulting from patch mosaic burning practices carried out by Pemón indigenous peoples in savanna-forest transitions. Photo: Ruth Salazar-Gascón

Making impacts

Lessons were learned about fire ecology, impacts and management, and also about the importance and enormous potential of integrating different sources of knowledge. Project scientists learned much through contact and exchange with the Pemón and indigenous CORPOELEC brigades, and this interaction changed the perspective of the research. The need to implement newly learned knowledge became evident, but it wasn't clear how to integrate more information from actors with such different perspectives. To answer this, the Proyecto Riesgo (Risk Project) and Proyecto Apök (fire in the Pemón language) were created, followed by others, supported by local and international funding.

All these projects were interdisciplinary and intercultural and were centred around safe meeting spaces that allowed dialogue between indigenous communities,

Workshop on integrating indigenous perspectives with academia and institutions in the Instituto Venezolano de Investigaciones Científicas (IVIC), Altos de Pipe, Caracas, Venezuela, January 2017.

(a) Closing speech by the president of the Kavanayén Council of Elders, (b) Pemón community member presenting the results of a fire management working group, (c) Exchange of knowledge between firefighters, INPARQUES officials, academics, and members of indigenous communities, and (d) workshop participants. Photo: Maiquel Torcatt

academics and government institutions. They aimed at developing a truly inclusive approach to fire management in the park. Indigenous youth were trained as community researchers, and were responsible for interviewing elders and collecting ancestral knowledge and practices related to fire use, shifting agriculture and hunting (Bilbao et al. 2021). Training workshops contributed to building capacities in using photography and video to document traditions and good practices. A new fire management paradigm began to be collectively conceptualized. This approach integrated indigenous Pemón knowledge on the use of fire, information on fire ecology from academics, and technical knowledge from fire control authorities.

This work was consolidated in a 2015 workshop involving representatives from Pemón and Yekuana communities, and indigenous Makushi, Wapishana and Kayapo peoples from Brazil and Guyana. In 2017 and 2018, national workshops included indigenous communities and 25 national public and private organizations. They promoted participatory and sustainable fire management, and called for unity between academics, governmental bodies and indigenous peoples to support joint actions and respectful inclusion of indigenous knowledge. In 2018, as a result of the agreements reached, implementation began of an intercultural mechanism for IFM in the east of the park (Gran Sabana). These pioneering activities involved two-way training, with the Pemón providing training in patch mosaic burning and other indigenous fire prevention techniques to park authorities and forest firefighters, while also receiving technical training.

In 2019, following a presidential initiative, forest fire brigades throughout the country were expanded to 10,000 personnel, with training for 3,400 male and female firefighters; 1,800 of them are currently progressing toward university degrees as higher technicians and graduates in fire science and fire safety. This in-service education and training includes elements of IFM in a new operational philosophy for firefighters. They do not just intervene in fire control, but also work as local managers who facilitate intercultural dialogue and replace the fire exclusion model with community fire management.

A permanent working group for integrated fire management in Venezuela was formed in 2021,

including researchers and academics, and officials from environmental, territorial management, public safety and emergency response agencies. They are committed to promoting the methodological development of IFM with an intercultural vision and disseminating this approach at the national level through webinars and workshops. The park's forest fire firefighters have now incorporated lessons learned throughout this process in their training programmes, applying IFM techniques in protected areas throughout the country and exchanging experiences in integrated and participatory fire management with national and international experts.

These experiences are now being included in a new national system of IFM. It is promoted by an intersectoral team that includes public officials representing the INPARQUES forest fire firefighters, the Forest Fire Protection Directorate of the Ministry of Ecosocialism, the Vice-Chair of IPCC Working Group II on impacts, adaptation and vulnerability, and academics who have promoted these actions.

Work also continues at the regional level, building on the Participatory and Intercultural Fire Management Network established in 2015. A joint declaration expresses the commitment of actors in Venezuela, Brazil and Guyana to legitimize and strengthen indigenous fire management in regional fire policies. For example, the Cobra Collective and Simón Bolívar University are sharing lessons to provide a basis for developing scenarios for use in all of tropical America. Given that fire has historically been seen as a driver of deforestation and a emitter of greenhouse gases, experiences in Canaima National Park represent an innovative alternative in managing fire to mitigate climate change.

Conclusions

This research revealed a sophisticated indigenous knowledge system on the use of fire in livelihood activities, and collaborative burning practices at savanna-forest boundaries to protect forests from catastrophic wildfires. In contrast, studies showed that fire exclusion increases the risk of more severe fires due to fuel accumulation, a situation worsened by drier and warmer climatic conditions.

Inclusion of indigenous peoples, firefighters, public officials and academics in field research and dialogue on socioecological aspects led to a paradigm shift that values Pemón knowledge and culture in sustainable resource management and adaptation to climate change. This led to the adoption of integrated and participatory fire management principles by the INPARQUES forest fire firefighters. Management plans also increased indigenous peoples' trust and involvement.

Further efforts are still needed to support the participatory development of viable plans and implementation of integrated fire management with indigenous communities throughout the region and the country. The immediate needs are to build organizational platforms with the necessary technical and financial resources, with institutional support structures that transcend sectoral approaches.

The use and value of fire as a land management tool and the reintroduction of traditional indigenous practices must be incorporated into a national integrated fire management plan with an intercultural vision. This must also be complemented by technical and professional training, research on fire dynamics and use of fire as a tool for climate change mitigation, alongside a system to effectively monitor and evaluate fire occurrence in real time to optimize planning and intervention efforts and assess the impacts of past, ongoing and future programmes.

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Prescribed burning in a protected area as part of integrated fire management. Photo: CeMAF

2.2

Integrated fire management in the Brazilian Cerrado: advances and challenges

Micael Moreira Santos, Jader Nunes Cachoeira, Antonio Carlos Batista, Eduardo Henrique Rezende, Maria Cristina Bueno Coelho, and Marcos Giongo

"The results of integrated fire management actions show that zero-fire policies have not resolved the problems arising from forest fires and irregular burn."

Introduction

Fire is an important evolutionary agent for plants and has played a considerable role in the distribution of savannas across the world. Fire-prone plant formations, in areas including savannas, cover about 40% of the earth's surface (Bond et al. 2005). The Brazilian Cerrado, which covers an area of 2,036,448 km², the second-largest biome in the country, is an example of an environment that has fire-dependent types of vegetation. Several adaptations to fire are the hallmark of the endemic flora of the Cerrado, including arboreal and herbaceous species with ability to store water and nutrients, thick bark, sparse branches and thick leaves, among other characteristics. Despite the dependence on fire and the presence of fire adaptation mechanisms in savanna environments such as the Cerrado, however, the increase in the frequency of high-intensity fires, especially in the late dry season, has negative effects on the ecosystem through increased plant mortality (Oliveras et al. 2012).

Evaluation of fire behaviour in a prescribed burn. Photo: CeMAF

Fire in the Cerrado is generally not attributed to natural ignition, and there is no doubt that human activity has been the main cause of forest fires over the years (Coutinho 1990). People have always used fire, either as a good tool used by traditional and indigenous populations for their subsistence, or in bad ways, such as the irresponsible burning of pastures in the critical months of the dry season. This latter practice is one of the main causes of forest fires in the Cerrado biome.

Managing the use of fire

Integrated fire management (IFM) is not a new practice in Brazil; it has been carried out since prehistoric times. The use of fire as a management tool was later passed from indigenous peoples to the *sertanejos* (people from northeastern Brazil) in the Cerrado and Campos Sulinos regions. Fire was used for managing native pastures in extensive cattle raising (Pivelo 2011). Indigenous peoples continued to use fire for hunting, religious rituals, land management for agriculture, pest control and fuel management. The use of controlled fire is also important in maintaining gardens, adding nutrients to the soil, eradicating pests and weeds, and preventing more severe fires (Levis et al. 2018). The uses of fire in territories of indigenous communities (*quilombolas*) and other traditional communities also include symbolic acts, confirming their relationship with the landscape, and involving collective and cultural practices at various scales (Posey 1985).

It is important to highlight not only the existence of "good" fires resulting from traditional management practices that were carefully carried out, but the fact that people have always over-used fire in land occupation, deforestation, burning of residues and pasture management. The increase in uncontrolled wildfires resulting from these irresponsible burning practices has became increasingly apparent. Consequently, fire in general is considered as something that should be avoided.

The Forest Code of 1934 was the basis of the fire prohibition policy, and it considered traditional fire practices as an enemy to be fought. This policy was further enforced from the 1980s on to limit deforestation in tropical forests. It also applied in grasslands and savannas, in spite of scientific and cultural evidence that the role of fire in such ecosystems is fundamentally positive (Durigan and Ratter 2016).

Changing ways of thinking

With an increased number of policies prohibiting the use of fire and the consequent accumulation of combustible material, the frequency and severity of forest fires have increased, especially in protected areas. Large and frequent fires have also highlighted the financial and resource limitations of the public institutions responsible for controlling them (Barradas et al. 2020). It should be noted that the consequences of such policies had already been seen in other countries, such as the United States, South Africa and Australia.

In 2012, the views of public institutions regarding how to deal with fire started to change, shifting away from

fire exclusion policies in protected areas, primarily in the Cerrado, to a concept of fire inclusion. This transition was completed in 2014, with the first pilot projects for integrated fire management in various protected areas. This first pilot projects were driven by the Cerrado-Jalapão project, carried out through a partnership between the Governments of Brazil and Germany..

So despite integrated fire management being ancient, its reclamation as a practice to prevent forest fires in protected areas in Brazil is very recent. And controlled burning combined with traditional knowledge, to be used in biodiversity conservation, still lacks approval as an official public policy. IFM also required strengthened operational and technical capacity.

Changing legislation

Historically, Brazilian policy on the use of fire focused on restricting its use. Since the 1600s, fire has been a concern to public institutions and society in general, with specific regulations that restricted the use of fire in brazilwood forests and agricultural fields. The Forest Code of 1934 prohibited the use of fire for the most purposes, and in some cases the use of fire was defined as a crime subject to a fine or even imprisonment. The subsequent Forest Code, in 1965 (Law No. 4771), continued with the same prohibitions. However, despite banning fire in forests, both measures justified the use of fire in agropastoral or agroforestry practices, if permission was established through an Act of government.

The country's first national park was created in 1937. In 1979, national parks were regulated, with measures that prohibited practices that could cause fires in conservation units, although the use of managed fire was allowed in certain circumstances. Then in 2012 a revision of the Forest Code (Law No. 12,651) allowed the use of fire in protected areas for the conservation of fire-adapted ecosystems, provided that the specific use of fire was described in their management plan.

Most recently, in 2018, Bill No. 11,276 was drafted to bring a new legal perspective to IFM strategies by establishing a national policy for integrated fire management. This would lead to the establishment of regulations for the use of fire as a practice for preventing and fighting forest fires in natural areas, and for the use of fire by traditional populations such as *quilombolas*, indigenous people, and family farmers. However, this bill has not yet been fully approved, and ratification by the Brazilian Federal Senate is still pending.

Organizational structure

Fire management in Brazil is carried out at federal, state, municipal and private levels. At the federal level are two main executing agencies: the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), and the Chico Mendes Biodiversity Institute (ICMBio). ICMBio is responsible for managing conservation units under the government's jurisdiction, including the hiring of fire brigades. The federal government also created the National System for the Prevention and Combat of

Institutional partnerships support the development of research and improvement of tools for integrated fire management activities. Photo: CeMAF

Scientific research activities carried out in prescribed burning actions of integrated fire management. Photo: CeMAF

Forest Fires, which is coordinated by IBAMA. This aims to develop integrated programmes to monitor, prevent and fight forest fires. It is also responsible for developing and disseminating information about controlled fire management techniques, carrying out staff training and raising public awareness of the risks of inappropriate fire use.

Monitoring

Monitoring the behaviour and dynamics of fire provides extremely important information for public managers in deciding on actions to take related to integrated fire management. Most national forest fire monitoring is carried out by the National Institute for Space Research. Its Queimadas programme undertakes research in and develops innovative products, processes and geo-services for monitoring and for modeling the occurrence and propagation of fire. Monitoring includes the detection of fire-prone ares in vegetation. It also includes spatial and temporal analyses of fires through the Burning Database system (BDQueimadas), which automatically updates data daily, with free and open access to all maps, tables, graphs and other information. Another important tool is the MapBiomas platform, which provides time series data (since 1985) on land use and cover, deforestation, fire scars, and regeneration, among other factors. Mapping of fire scars, for example, includes annual and monthly data, frequency of occurrence, classification of coverage and objective of the fire. Monitoring is also carried out at the state level; see Box 1.

Box 1. Centre for Environmental Monitoring and Fire Management

In the State of Tocantins, 90% of which is in the Cerrado biome, annual monitoring is carried out for all of its 139 municipalities. The Centre for Environmental Monitoring and Fire Management (CeMAF) at the Federal University of Tocantins records data on fire scars and forest fires. This information is used by state and municipal authorities in the implementation of public policies, and in firefighting and fire prevention strategies. The centre was conceived of as a place for developing instruments and methodologies to support actions that prevent, reduce and combat forest fires and irregular burning. Combining research, teaching and extension actions, it brings together scientific knowledge on the implications of fire in the Cerrado, trains personnel, and disseminates information on fire management. CeMAF is affiliated with the Global Fire Monitoring Center (GFMC) in Germany and is part of one of its eight regional centres, the South America Regional Fire Management Resource Center. CeMAF has annual maps from 2000 to the present year, and maps with almost monthly frequency for some places. Based on mapping data, an average of 3.2 million hectares, or approximately one-eighth of the state, burns every year.

Tools and technologies for fire management

With the decriminalization and reintroduction of the use of fire by public institutions, experiences over recent years have made apparent the need for more and better tools. These deficiencies are gradually being addressed, and new methodologies have increasingly provided greater accessibility and ease of operation, both for public managers and for the teams who work on the front line of fire management, firefighting and fire prevention.

This includes remote sensing for mapping combustible material. It provides data on the physiological condition of vegetation (i.e., dry or green), which is of considerable importance in planning prescribed burning in protected areas. The information can also be accessed by indigenous people and other residents through smartphones. Drones are another tool that help improve procedures and decision-making in various ways.

Challenges

Despite increased understanding of the benefits of integrated fire management in the Cerrado, little is known about different environments, including fire-sensitive ones. In addition, it is necessary to validate existing methodologies and develop new tools in order to facilitate the planning of actions.

Despite the general recognition by ecologists that total fire suppression is not beneficial to the maintenance of savanna ecosystems, there is still a need for clear guidelines on how to use fire. There remains a policy gap in dealing with fire, especially outside protected areas. Legal regulation is essential, not only to define the rules to be followed, but to provide greater legal certainty for fire management actions.

Integrated fire management in protected areas has been implemented and accepted only recently, and decision making in response to forest fires in Brazil by government agencies has generally been more reactive than proactive. IFM is still not widely accepted in conservation debates in Brazil.

Although there has been visible progress with the implementation of integrated fire management, it is still restricted to protected areas, and is not carried out in privately owned areas. This is an issue that still needs to be resolved, since most forest fires start in private areas.

Furthermore, little is known about the effects of climate change on traditional fire-use regimes or on the practice of prescribed burning. Research is needed to define more specific criteria for the use of fire under various climate change scenarios, and to assess the potential for integrated fire management actions to reduce greenhouse gases.

Conclusions

Integrated fire management involves a set of techniques, principles and methodologies that allow the use of fire

Different institutions working together to collect information on biomass and fire behavior after prescribed burns in the Cerrado, Jalapão region, Tocantins. Photo: CeMAF

in order to achieve economic, social and environmental benefits. It has legal support in the 2012 Forest Code, which allows the use of fire in places or regions whose circumstances justify the use of fire in agropastoral or forestry practices, with authorization from the responsible environmental agency.

In the Brazilian context, integrated fire management can play a fundamentally important role. By including local knowledge, IFM is sustaining an ancestral practice for reducing forest fires and conserving ecosystems. For effective integrated fire management in private areas, however, it is necessary to develop programmes that include land owners, and to evaluate ways of expanding the proposed system.

Reintroducing integrated fire management in the Cerrado has brought new tools and technologies that improve planning and implementation. Investment in research and development must be continuous, in order to advance technologically, and to train technicians, traditional communities and land owners. And it remains essential to reconcile new technologies and methodologies with traditional knowledge about fire management.

More scientific knowledge is also needed regarding greenhouse gas emissions from the traditional use of fire, and to assess the climate change mitigation potential of integrated fire management practices.

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Fire runners managing a controlled burn along with young family members, so they can teach them the skills. Photo: Laura Patricia Ponce-Calderón

2.3

Fire management in pyrobiocultural landscapes, Chiapas, Mexico

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"Only through valuing and understanding the context of cultural fire management can the socioecological benefits of fire be maximized"

Introduction

In Mexico, 71% of indigenous territories are biocultural regions. These are areas with high levels of biodiversity associated with ethnocultural diversity, where people seek a way of living that is in harmony with their values. Cultural practices are rooted in agriculture and incorporate fire, as seen throughout Mesoamerica in the *milpa* system where burning enhances soil fertility through providing ash. Fire is also used historically in medicines and ritual ceremonies and in livestock and forest management (Ponce-Calderón et al. 2020). Memory and territory underlie the patterns of life and culture (Limón-Aguirre and Pérez-Tadeo 2018).

Communities in Chiapas are pioneers in fire management (Rodríguez-Trejo 2015); for example, land users have to request burning permits from village organizations, following customary environmental management practices (Ponce-Calderón et al. 2020; Guevara-Hernández et al. 2013). This article

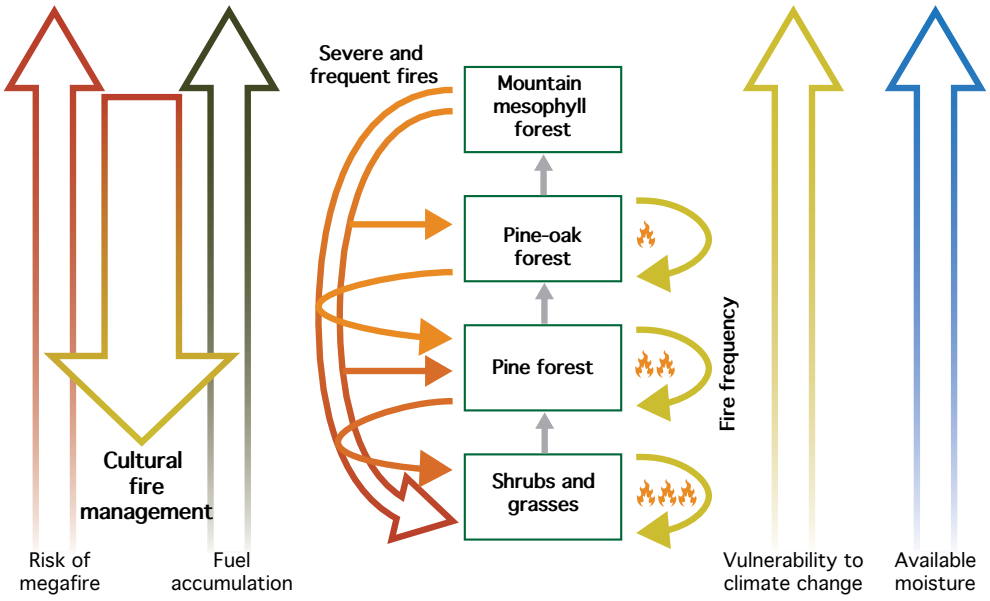

Figure 1. Model in which cultural fire management determines processes that can reduce the risk of extreme fire events. Adapted from Ponce-Calderón et al. (2021).

reports on the cultural management of fire by indigenous Antelá and Tziscao communities in and around Lagunas de Montebello National Park, Chiapas, Mexico. It addresses territoriality, memory, fire regimes and management, and the integration of cultural knowledge and perspectives, with global relevance for all Indigenous peoples.

In Antelá, the Tojol-ab'al ethnic group use fire in their farming systems, whereas fire is prohibited by the Chuj community in Tziscao, and in both, as elsewhere, public policies aim to eliminate the use of fire from farming and other activities in protected areas.

The region contains mixed conifer forests dominated by pine, oak and *Liquidambar* (sweet gum) species, and humid montane vegetation. Three fire management histories are identified: (i) areas where fire is used for agricultural purposes, (ii) fire exclusion areas with no human settlements, and (iii) fire exclusion areas with human settlements (Figure 1).

The cultural context of fire management

This article defines "territory" as the space that allows and favours cultural life, and where history acquires significant dimensions (Limón-Aguirre 2012) and defines "territoriality" as the symbiotic way in which people inhabit these places. Cultural fire management is rooted in historical experiences and the territoriality of communities. This management is based on evidence, knowledge and experience with practices of sustainable treatment of nature in diverse spheres, including religion, the home, agriculture, livestock and forest protection.

People who establish a respectful relationship with their territories do so by constantly renewing their intimacy, co-dependence and communication with the different beings and elements living there. Sources of knowledge support fire practices that are beneficial for inhabitants, ecosystems and socioenvironmental processes. When this "pyrobiocultural" use of fire has been established, prohibiting it is anathema to the ways of life of entire peoples and cultural communities.

Box 1. Introducing "pyrobiocultural"

"Pyrobiocultural" is a new term that the authors of this article (among others) have been developing over recent years, having previously appeared in unpublished reports (as "pirobiocultural" in Spanish). It builds on the concept of biocultural landscapes from the early 2010s, and of biocultural diversity, defined as "the interdependence between biological and cultural diversity, indicating how significant ensembles of biological diversity are managed, conserved and created by different cultural groups" (Merçon et al. 2019). When analyzing the important role, use, benefits and impacts of fire in a landscape or territory, it seems appropriate to have a specific term that implicitly incorporates all of the diverse social, cultural, ecological and economic components.

Brigades with members from different communities work together to clear firebreaks and remove combustible material to reduce the risk of wildfires in Lagunas de Montebello National Park. Photos: Eduardo Castellanos

Indigenous customary principles shape and modulate sustainable practices by ensuring the interests of present and future inhabitants. They also guide practices, such as the use of fire, that shape territoriality and contribute to the collective identity of Indigenous peoples. For example, there is an understanding among the Chuj and the Tojol-ab'ales, respectively, that everything — including fire — has its *pixan* or *altsil*, a pseudo-soul, such as the "earth that gives life," "blessed water," "the hills, wind, crops" (Limón-Aguirre and Pérez-Tadeo 2018). From this perspective, fire is not only an element of nature, but also a "being" that participates in everyday life as a messenger and that is present in ceremonies and festivities (Ponce-Calderón et al. 2020), and so its cultural dimensions must be studied comprehensively.

In ancestral Maya Chuj-tojol-ab'al territory, the spiritual dimension of fire calls for dialogue and reflection; fire must be spoken to, forgiven and respected (Limón-Aguirre and Pérez-Tadeo 2018). As Ysidoro Morales of Tziscao clearly expressed: "with fire, air, water, we must understand how they function and when they should be used, so that we also know how to enjoy and take care of them, and to be careful too, because otherwise they can come against us."

One of the most important resources of indigenous cultures and their territorialities is memory (Toledo 2005), and it influences decision-making. The loss of historical memory regarding the use of fire can be a factor that can lead to more forest fires, but in Lagunas de Montebello National Park, memory is still a valued resource for cultural knowledge and for the renewal of territoriality for future generations. For local indigenous people, fire in general has positive connotations, which is often referred to in an affectionate way as *fueguito* ("little fire" in Spanish). Wildfire, in contrast, is considered negative because it can burn everything in its path, although it may still be a messenger.

In this region, changes and imposed fire-use restrictions have drastically modified socioecological processes and have restricted cultural practices, which has altered the cultural regime of fire (Ponce-Calderón et al. 2021). These changes occurred after a major wildfire in 1998, when the government reacted by reinforcing a strategy of fire exclusion in the area.

Cultural fire regimes and management

Two different types of fire regimes are present in the study region: ecological and cultural.

Ecological fire regimes address the characteristics of fire (frequency, severity, intensity, seasonality, duration, among other factors) composition, structure and dynamics of ecosystems. However, cultural fire regimes — in other words, the use of fire when carrying out productive and cultural practices, based on collective interests — must also be understood. This includes the experiential wisdom that provides an orientation and framework for the cultural management of fire, as well as criteria and resources for its controlled use. The parameters of a cultural fire regime include cultural knowledge of the use and management of fire, technology (techniques and methods to facilitate the work), community organization, community norms or agreements, respect (values), territory, identity (lifestyle),

Firewood collected from the forest and, like fire, integral to community life. Photo: Laura Patricia Ponce-Calderón

vitality, transmission of knowledge and permanence. A cultural fire regime corresponds to a pyrobiocultural territory, where there is a strong relationship between the use of fire and local understanding that relates to social needs within the territory and the presence of fire-dependent, fire-sensitive and fire-influenced ecosystems.

Cultural fire regimes use fire in a respectful manner, prioritizing and maintaining a historical way of life that is in harmony with nature. A cultural fire regime is based on traditional wisdom about the cultural management of fire. Fire does not represent a negative impact on the ecosystem or the community. However, this regime can be altered in three ways: (i) by prohibiting the use of fire in a territory; (ii) using fire excessively due to negligence, disagreement or failure to consider all circumstances; or (iii) through the loss of knowledge about its use. These affect the socioenvironmental system in the medium or long term, and can consequently lead to more forest fires.

Practices persist when they are rooted in collective memory and meet the needs of communities. The cultural management of fire, born within villages, involves the integration of fire use and management practices that increase the production and reproduction of cultural life and sustain the management of the cultural territory. This is reflected in cultural knowledge that results from cognitive inheritance, context analysis, territorialized experiences, and the realization of a desire for a full and rewarding community life. To provide the essentials of life, such as food, fire has to be used in an effective manner. Ponce-Calderón et al. (2021) demonstrated the comprehensive effectiveness of practices associated with fire in forest ecosystems, such as opening clearings that allow for the regeneration and increased growth of trees, while also reducing the frequency and impact of forest wildfires by removing fuel loads.

In the national park, there is cultural knowledge, along with circumstances and conditions, that is conducive to the implementation of this type of fire management. An example is the presence of people culturally identified among the Chuj as *corredores de fuego* ("fire runners"), who are experienced in the use of fire, and knowledgeable about the variables that determine a good burn and about the techniques for fire control. People respect their knowledge of how to carry out cultural fire management, as this knowledge is needed to coexist with fire and with nature as a whole, and community life depends on it. Fire management actions are based on ecological principles, but they also incorporate economic and political factors, and even aesthetic considerations, constituting guidelines for conscious, humane, supportive and fair management for all people (Limón-Aguirre 2012).

Cultural fire management

Cultural fire management represents a promising approach for the region by reducing the risks of and impacts from wildfire (Ponce-Calderón et al. 2021). The following practices are common in the study region, and could be complemented and cross-culturally enriched into an integrated regional strategy.

1. Collecting firewood. Fire behaviour is influenced by fuel load, weather and topography, with fuel the only factor that can be manipulated. Collecting firewood can reduce fuel loads, which can in turn prevent catastrophic wildfires, such as those that occurred in 1998 (Ponce-Calderón et al. 2021).
2. Creating and maintaining firebreaks. This should be a priority in areas with higher wildfire risk to provide anchor points for fighting fires or for stopping their advance. They should be used by inhabitants and administrators of the park.
3. Observation from wildfire detection towers. When observers see smoke, they immediately alert the authorities, which allows the source to be promptly detected and controlled. The towers are operated by forest health brigades, community surveillance teams and staff from the National Commission of Natural Protected Areas (CONANP).
4. Removing combustible material. It is important to remove fallen trees, such as those that have blown over or been killed by pests or disease. Within the national park, people in neighbouring communities can take such woody material away at no cost following a written request.
5. Organizing local people for agricultural burning. This is an important three-phase process with various activities and considerations for a successful burn (Figure 2).
6. Cultural burning. These burns are carried out on forest land, in conjunction with the authorities, with the strict purpose of reducing fuel loads. These burns can have a range of local and institutional objectives.
7. Integrating cultural skills and knowledge. In the region, “fire runners” are culturally significant and can be practical teachers to youth and people from other regions in agricultural, cultural or controlled burns. They are also crucial in defining policies and strategies, maintaining the cultural value of fire, and in renewing memory as an ecosystem resource.
8. Integrating community fire-management committees. Many committees already exist and in some cases are supported with equipment and training by government agencies. It would be a step forward if these committees and people with cultural skills were integrated into broader regional fire-management committees that also include authorities that define fire-related policies, strategies, needs and priorities. In addition, an evaluation meeting should be held after a fire. This will help committee members better understand how to reduce the risk of wildfires (Bilbao et al. 2019).
9. Selecting priority wildfire risks and danger areas according to biocultural values. These values should be selected by the communities themselves. To determine those areas with a greater risk of wildfire, it is important to involve community members who know their territory, and who value certain historical or cultural elements.

Workshop on social mapping, where community members identify priority wildfire-risk areas. Photo: Liliana del Carmen Maldonado Pérez

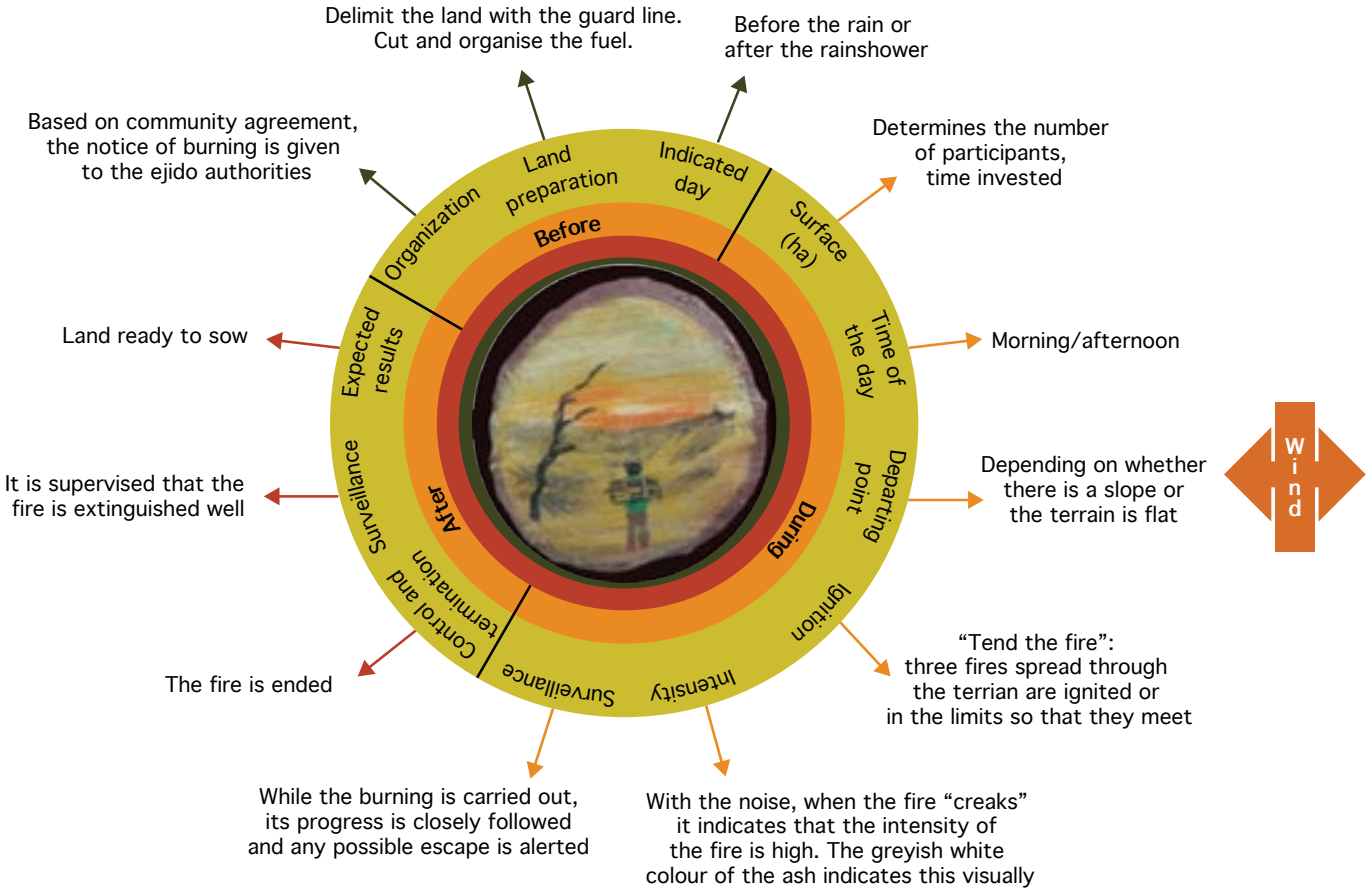

Figure 2. Cycle of application of agricultural burns. Source: Chuj artist from El Quetzal, Nentón, Huehuetenango, Guatemala.

These practices integrate social, ecological, cultural and political aspects into the ways in which people territorialize the space in which they live. In doing so, people adapt new technologies, technical knowledge and theoretical assumptions from a range of knowledge systems. This approach includes cultural fire-management practices as a core element of community life. As expressed by one of the world's leading fire scholars, "The most productive future for fire research is to create fire cultures and reconcile traditional practices with modern society" (Stephen Pyne, pers. comm., 2019). Traditional practices must be taken into account when developing strategies for integrated fire management that take a participatory and intercultural approach (Bilbao et al. 2020).

Interculturality

Cultural fire management is subsidiary to the integrated and intercultural management of fire. The concept of "interculturality" is used here is opposed to the term "monoculturalism," which increasingly governs legal and knowledge frameworks. Traditional knowledge and ways of life must be recognized and endorsed by external agents in practical and everyday terms in order to arrive at an intercultural approach that can effectively guide the development of policies and programmes of public interest.

Dialogue, sharing knowledge, and a determination to incorporate cultural knowledge frameworks are key factors that can lead to a more sustainable, equitable, democratic and just world (Rodríguez et al. 2018). Interculturality is crucial to achieving respect for and appreciation of traditional fire-use practices that are otherwise being increasingly prohibited. It is also necessary so that communities are no longer seen as fire starters but as fire managers (Sletto and Rodríguez 2013; Rodríguez et al. 2018). An excellent example of this intercultural approach is that of indigenous peoples in the northern Amazon region (Bilbao et al. 2019).

Conclusions

The world is witness to the impacts of external social actors imposing their technical and political visions on cultural knowledge, and therefore, on pyrobiocultural territories and the people and ecosystems they contain.

However, indigenous peoples have moral and ethical rights and obligations to strengthen their relationship with the land they live on, and to keep their knowledge alive. This includes cultural fire management that is based on a diversity of knowledge from ancestral cultures and that prevents and controls fires while considering socioeconomic, cultural and ecological needs.

It is only through valuing and understanding the context of cultural fire management that the socioecological benefits of fire can be maximized. Moreover, to address the problems of extreme climate events that can lead to megafires, a truly open intercultural dialogue is required that considers local experience and knowledge to be valuable. The resulting cultural fire-management schemes should be incorporated as part of participatory community strategies, to be respected by the institutions in charge of fire prevention and firefighting. Such alliances must be encouraged and enhanced to ensure the maintenance and enhance the potential of pyrobiocultural regions as part of Mexico's national fire-management strategy.

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2.4

Wildfires in the Paraná Delta, 2022. Photo: Civil Protection and Risk Management, Santa Fe Province, Argentina

Traditional knowledge of fire use by islanders in the Paraná Delta, Argentina

Adriana Millán, Brián Ferrero, and Bibiana Alejandra Bilbao

"Listening, learning and encouraging community participation is a fundamental part of building a much-needed dialogue to reduce wildfire risk."

Introduction

The Paraná River Delta is the culmination of the second largest river in South America. Together with the Amazon and the Orinoco, the Paraná River provides more than 30% of the planet's renewable freshwater. This subtropical area is distinguished by its biogeographic and ecological uniqueness, with a high species diversity in its complex mosaic of wetlands. Its islands are the home of communities involved in small-scale fishing and hunting, raising cattle and other livestock for their own consumption and sale, and beekeeping (Ferrero and Arach 2020). Livestock farming has been important to the economy since colonial times and is based on grazing highly productive natural pastures (Massa 2012).

For several decades, this area has suffered from major wildfires. In 2020, coinciding with an extraordinary drought and a historic low level of the Paraná River, intense wildfires affected 487,000 ha (MAyDS 2021). The

Typical landscape and homestead in the upper delta of the Paraná River. Photos: Maiquel Torcatt

response to the crisis was considered insufficient by civil society, who through massive public demonstrations demanded that the government control the wildfires and pass laws to protect the wetlands and regulate industrial and real estate activities on the islands. The problem received extensive coverage in the national and international media, which devoted headlines to discourses that emphasized the negative aspects of fire, such as the loss of biodiversity and risks to human health.

The government responded by reinforcing fire suppression and control policies and tightening regulations that criminalized the use of fire. This negatively affected local communities and small livestock producers, who depend on the use of fire for their subsistence activities.

This article summarizes for the first time the traditional use of fire in the delta, and describes efforts to stimulate dialogue between local communities, environmental organizations and government agencies to share perspectives and come to a common agreement as to ways forward. Results of these efforts indicate the islanders' complex knowledge of the role of fire in the maintenance of the various grassland ecosystems, and show that dialogue can lead to effective and workable solutions.

Evolution in fire management

The use of controlled fires in the Paraná Delta to improve pasture for livestock was described as early as 1830, by Alcides D'Orbigny, but today, wildfire is also a recurring phenomenon. As cattle ranching developed, pasture burning began to take place towards the end of winter (late dry season), and in spring (August to October). When the river attains its lowest level, fires become more intense and extensive, because fuels and soils are drier, and watercourses and lagoons are smaller; these water bodies otherwise act as effective natural barriers to an advancing fire.

However, the availability of biomass and climatic factors are not alone sufficient to explaining the changing fire regime. Environmental organizations and government agencies consider that increased wildfire occurrence has resulted from the transformation in livestock activities on the islands, with a corresponding increase of fire use in land management. This became the dominant discourse, and the perspectives of the islands' people on the use of fire were not heard.

In response to more wildfires, institutional approaches focused on fire exclusion and on firefighting policies aimed at suppression. After the fire crises of 2020, forest fire brigades were created and others were strengthened, with the establishment of beacons (*faros de conservación*) for early detection of fires, the expansion of protected areas, and the reactivation of inter-jurisdictional territorial management agreements between the provinces of Santa Fe, Entre Ríos and Buenos Aires. The Integral Strategic Plan for Conservation and Sustainable Use in the Paraná Delta (PIECAS-DP), created in 2010, was revised and reactivated in 2020 as a result of the outbreak of

major wildfires. Despite differences between the three provinces, all provincial regulations covering the upper Paraná Delta prohibited the use of controlled fire by local communities in managing their land.

At the national level, the notion of criminalization of and penalization for the use of fire has deepened. In December 2020, Article 22 of National Law 25.815 was modified to establish a ban on changes in land use in areas affected by wildfires. However, the high cost of implementing suppression policies, and their limited effectiveness, generated social, cultural and governance conflicts, especially in conservation areas.

In this complex context, where multiple actors, interests and perspectives collided, possible actions for and solutions to the fire problem were sought. A series of projects emerged that began to give voice to the islanders, who were otherwise underrepresented in public discourse. In mid-2021, this led to the project Strengthening the fire management of the Paraná Delta Ramsar Site (SRDP), funded by the Canada Fund for Local Initiatives. This aimed to develop climate change adaptation and mitigation strategies related to wildfires through participatory diagnosis, increased awareness of institutional actors, and integration of scientific and local knowledge about fire. The project investigated the different considerations of fire among actors in the area, to propose alternatives to the problem of wildfires under the conceptual framework of integrated fire management. At the regional level, the aim was to understand the relationship between fires, wildfires, agricultural change and public policies, and the socio-environmental conflicts that unfolded after the wildfires in the delta in 2020.

Methodological approach

The research described in this article explored the dimensions of fire use and its actors – aspects that are little studied or understood in the region — to identify opportunities to promote a paradigm shift from fire suppression to integrated fire management. The first steps assessed the practices and meanings of fire among local inhabitants, civil society organizations, governmental bodies and academic institutions. Due to antagonism among the different groups, however, each was approached in a different way in order to generate an atmosphere of trust and respect for other participants and their perspectives.

Interviews and group meetings were held with community members whose productive activities take place in islands near the towns of Puerto Gaboto, Sauce Viejo, Rosario, Monte Vera, Santa Rosa de Calchines and Las Masitas and the city of Santa Fe. See Figure 1. Ten environmental organizations from all over the region participated in a workshop in the city of Rosario to generate participatory diagnoses of the fire problem and identify possible solutions. Later, a symposium was organized with representatives from academic institutions and the governmental agencies responsible for environmental and fire management policies, who exchanged their perspectives regarding the wildfire crisis in Paraná River Delta.

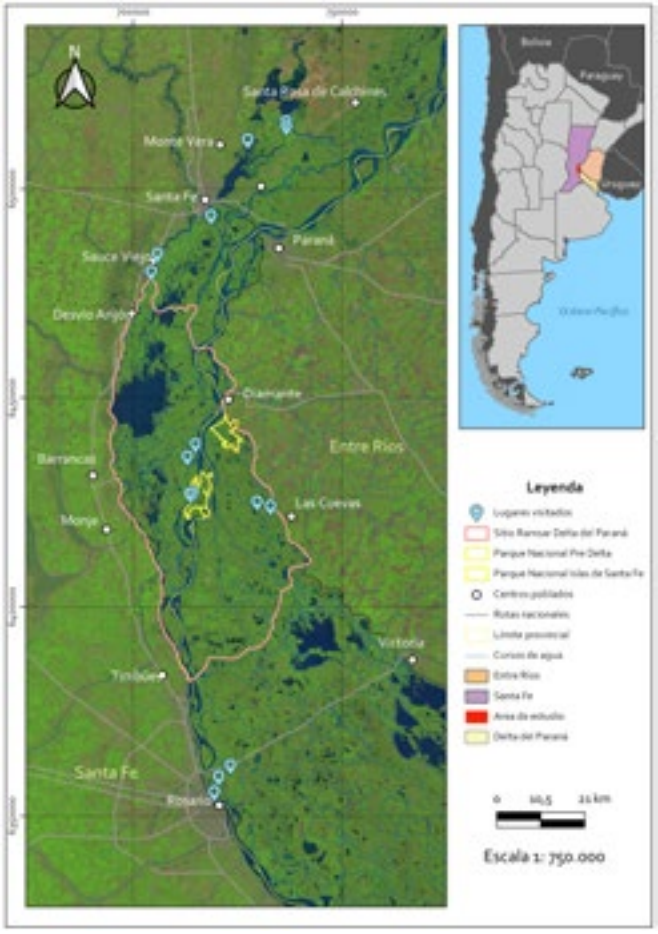

Figure 1. Location of the study area in the Paraná Delta. Source: The authors

Use of fire by local communities

Research results showed that fire has traditionally been used by the islanders, who say they cannot live without it. There is a wide diversity of fire uses, depending on the objectives, size of area to be burned, social organization and seasonality. In local terms for the uses of fire, the communities distinguish between domestic "fires" (*fuegos*) and landscape "burning" (*quema*), which are

Working groups in the workshop, "Burning and Fires in the Paraná Delta", Rosario, November, 2021. Photo: Maiquel Torcatt

both controlled, and "wildfires" (*incendios*), which are uncontrolled.

Domestic uses: Fire is used inside the house for cooking and heating, and outside for barbecues and burning green leaves to repel mosquitoes. Fires are controlled, protected and delimited — "socialized fire" — and integrated into daily domestic life.

Maintenance and renewal of pastures: This is widespread, burning dry pastures with no food value for cattle, which allows new, green, tender pastures to regrow. It is carried out in late winter and early spring (mid-August to mid-October), by one person alone or sometimes with a small group of neighbours. People who start these fires take into account the strength and direction of winds, the presence of watercourses and ponds that can act as barriers to fire spread, and whether rain is forecast for the following days.

Land clearing: This is a central use in the delta throughout the year. These fires are set following the same criteria as for burning for pasture regrowth. Fire is also used for "cleansing" around homes to eliminate plants where snakes, weasels or caimans can hide. People also create artificial firebreaks to be used for protecting homes and barns, and for backfiring.

Hunting: This fire use is generally considered problematic, as hunters are often outsiders and do not take the necessary precautions, so control of fires is lost.

Land management and control: Fire is also a tool for territorial affirmation, to show that land is being used, and is not left to nature. Fire was also historically used to decrease the silting of lagoons when the Paraná River flooded, by burning dry vegetation in these basins.

Different perceptions of wildfires

Although wildfires in the upper Paraná delta were perceived negatively by all the actors consulted, stakeholder groups had quite different perceptions of their causes and impacts.

Small and medium-sized livestock producers stated that wildfires arise from fires started by "others," to intimidate them by affecting their livelihoods, and so people on public lands are forced by the government to leave the islands. The increased occurrence of wildfires was seen a serious threat by local communities, creating mistrust and establishing the concept of "enemies" and confrontation.

Representatives of environmental organizations considered that the increase in wildfires resulted from the spread of industrial production. In particular, they felt that agricultural intensification on good land had displaced livestock production to marginal areas such as the islands of the Paraná Delta. This led to productive activities being perceived as poorly adapted to the area's social and environmental context. The climate crisis was also considered, highlighting the role of production models in the modification of regional climate patterns and phenomena such as drought and extreme low water

levels of the Paraná River, which favour the development of large wildfires.

Environmental organizations also thought that wildfires were inadequately managed by the governmental bodies responsible for the protection and conservation of the delta's wetlands. They felt in particular that the institutions in charge of fire suppression were ineffective, in spite of all the equipment and people available, and were unable to prevent the advance of wildfires and the damage caused, with wildfires being extinguished only following rains. Some civil society organizations expressed the belief that wildfires are used for political means, diverting public attention from the adverse economic problems the country is experiencing, and that wildfires may be linked to criminal activities in the area, such as drug trafficking, and even to outside pressure on local people in order to take their land.

The Ministry of Environment and Climate Change in the Province of Santa Fe considered all fire as alien to wetlands. As a governmental body that focuses on strengthening fire suppression policies, its representatives stated that its actions are related to regulations and that any use of fire is illegal and should be penalized. One reason given was the high cost of fire control. However, the government's civil protection agency, which is responsible for coordinating and executing fire management actions, stressed the importance of learning about local practices in the use of fire, and of creating alliances with different sectors of society, especially academic institutions with expertise in natural and social sciences, in order to design strategies to improve fire management.

Researchers involved in other disciplines were made aware of the impacts caused by wildfires, both ecological (negative effects on vegetation and soil) and social. They were especially interested in the social mobilization caused by wildfires, productive activities linked to fire, and the development of a combined socio-environmental approach that addresses the roles of fire in island life. Natural science researchers explained assessments of changes after a wildfire event in floristic composition, biomass and structure of plant communities, and soil nutrients. Techniques used included satellite images and high-resolution photographs from drones, coupled with field sampling and validation.

Opportunities and challenges

Integrated fire management considers sociocultural needs and the use of fire by local communities, alongside the ecological characteristics of a region. As such, it is important to consider the distinction between controlled burning and uncontrolled wildfires. Burning by communities for land management is undertaken under specific environmental conditions, which allows control over the extent of burning, fire intensity and rate of spread in order to achieve established objectives. Burning is carried out at specific times of the year; for example, when fuel, moisture and weather conditions are favourable for fire control (Bilbao et al. 2020). Burns turn into wildfires only when they get out of control, or if the necessary fire management considerations are not followed.

Fire is traditionally used in indigenous territories (*quilombolas*) and by peasant communities for cooking, heating, lighting, communication, pasture management, land clearing, soil fertilization, hunting, road clearing, security (keeping dangerous animals away), religious purposes, honey collection, brick making, and fuel reduction to avoid large wildfires, among many other uses (Bilbao et al. 2019). In the Paraná Delta, a study showed that the use of fire in grassland management improves forage quality for cattle (Zamboni et al. 2013). However, studies do not describe fire-use practices, or differentiate between different actors and their perspectives. This knowledge gap also contributes to perpetuating the concept that fire suppression is the only strategy for dealing with the wildfire problem.

The social dimensions of fire are now becoming more apparent to academic and government institutions. Studies have revealed that the use of landscape burning by local communities creates a mosaic of patches with diverse fire histories and differentiated fuel accumulation, which prevents the advance of fires in deliberately protected spaces (Bilbao et al. 2020). Burning also reduces the amount of combustible material, which reduces the risk of large wildfires. This in turn reduces greenhouse gas emissions (Russell-Smith et al. 2017) and supports the equilibrium of fire-dependent ecosystems, where the diversity of fire regimes (pyrodiversity) fosters biodiversity.

Conclusions

Fire is part of daily and productive life in the Paraná Delta region. The islands are a territory built on land and water, including the river's ebbs and flows and its sedimentation processes. It is a space constructed through livestock practices, hunting, and looking for wood and plants, with domestic fires and controlled landscape burns playing fundamental roles. However, communities' sustainable

practices have been forced to change since colonial times. This has affected landscape maintenance and promoted more frequent and intense wildfires, due in part to the accumulation of combustible material from unmanaged grazing land.

Following major wildfires in the delta over the past 20 years, civil society has mobilized to defend wetlands; government legislation on fire prohibition has been enacted, with resources mobilized for wildfire suppression; and there is growing academic interest from a range of sciences. However, local communities, in particular small livestock producers, have not participated in these discussions. Islanders' interests, knowledge and practices regarding fire, and their territory and way of life, were not included in these debates. Only now are their voices being heard.

This article investigates the actions carried out to address the problem of fires from an alternative perspective. Integrated fire management is proposed, based on an inclusive, participatory and intercultural vision that has proved successful elsewhere in South America (Bilbao et al. 2019). This approach builds on an understanding of the ecological and human dimensions of fire, and on the need to integrate diverse viewpoints on the uses of fire by local communities.

There is a clear need to establish platforms for continuous dialogue between local and national actors, and to acknowledge the positive aspects of traditional fire knowledge, which are fundamental to the conservation of cultural and fire-resilient landscapes in the Paraná wetlands. The goal now is to develop, refine and implement participatory tools for improved intercultural governance that will lead to a reduction in high-intensity wildfires.

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2.5

Controlled fire practice with Saraguro indigenous communities in southern Ecuador. Photo: Amazonía sin Fuego Programme

Ecuador's Amazonía sin Fuego Programme: a strategy for reducing forest fires

Daniel Segura, Joselyn Moreno, Lara Steil, Pietro Graziani, Andre Galvao, and Mauricio Velásquez

"We must rethink our view of fire, accept its presence, learn to live with fire, and change the way we manage land accordingly."

Introduction

Fire has been a part of agricultural, livestock, forestry and cultural activities that have shaped landscapes all over the world for thousands of years. However, uncontrolled fires have caused alarm, destroyed forests and natural wealth, put lives at risk and caused economic losses. In Ecuador, forest fires are defined as "fires that spread uncontrolled over all types of natural or planted vegetation, in natural or rural areas, produced by human action or caused by nature; causing serious environmental, climatic, economic and social damage, to the detriment of the natural heritage. Controlled burns for the disposal of agricultural residues and prescribed burns are not considered as forest fires" (GOE 2019).

Forest fires and climate change constitute a vicious circle, and the outlook is not encouraging. As the number of fires rise, so do greenhouse gas emissions, increasing overall global temperatures and the frequency of

extreme weather events. By the end of this century, the occurrence of forest fires is expected to increase by 50% (UNEP 2022).

This article reports on work undertaken in Ecuador since 2017 that seeks to generate a different scenario through the Programme *Amazonía sin Fuego* (PASF, Amazon Without Fires Program). This includes integrated fire management, and promotes alternatives to the use of fire in the country's highland and coastal regions.

Fires in Ecuador

Ecuador has exceptional biodiversity, apart from the Galápagos Islands. In its continental Sierra, Coast and Amazon biogeographic regions, there are 91 natural ecosystems covering 15.3 million hectares (ha) — 62% of national territory (MAE 2018) — 65% of which are forested. However, this natural wealth is under increasing pressure, which makes environmental management, land-use planning and the implementation of local and national development plans challenging.

According to the National Risk and Emergency Management Service of Ecuador (SNGRE), forest fires are the most commonly recurring adverse events in the country, making up 38% of such events between 2010 and 2019 (SNGRE 2019). Almost all fires are caused by negligent use of agricultural fires, or are intentionally set during land conversion, hunting, land conflicts, retaliation, vandalism, rubbish burning or other activities. The areas most affected include Andean moorlands, which supply much of the country's water resources, as well as dry forests, montane forests, and productive agricultural and forestry lands.

Between 2002 and 2019, an accumulated burned area of 598,880 ha was reported from 5,974 different fire events, with most fires occurring between September and December (Figure 1). More than half of this total area was burned in only five of these years, when more than 50,000 ha burned annually (GWIS 2022).

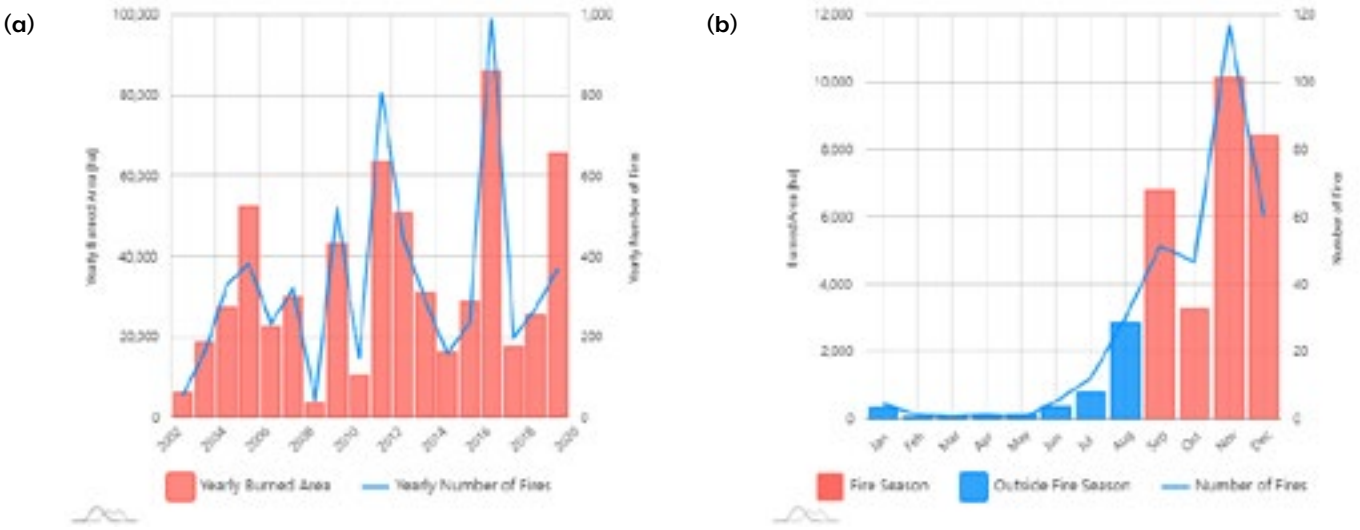

Figure 1 (a) Annual burned areas and number of fires; and (b) Average seasonality of burned areas (GWIS 2022), 2002–19. Data includes fires in all vegetation types.

National statistics agencies reported 20,137 fires between 2010 and 2021, which affected 202.618,38 ha (MAATE 2022): 80% in the highlands, 18% in coastal areas, and 2% in the Amazon and island regions (SNGRE 2022); see Figure 2. The most affected provinces were Carchi, Imbabura, Pichincha, Loja, Azuay, Chimborazo, Cañar, Cotopaxi and El Oro.

Integrated fire management

It is clear that forest fires cannot be prevented entirely, but their frequency and effects can be reduced considerably by applying approaches such as integrated fire management (IFM). The ultimate goal of IFM is to improve the conservation and management of landscapes at risk of fire. To achieve this, society must learn to coexist with fire, change the current perception of the general public and institutions that all fires are bad, and work to achieve fire suppression and prevention instead of the previous focus on fighting forest fires.

With the enactment of the Regulations of the Organic Environmental Code (R-CODA) in 2019 (GOE 2019), the national government took steps to align public policies

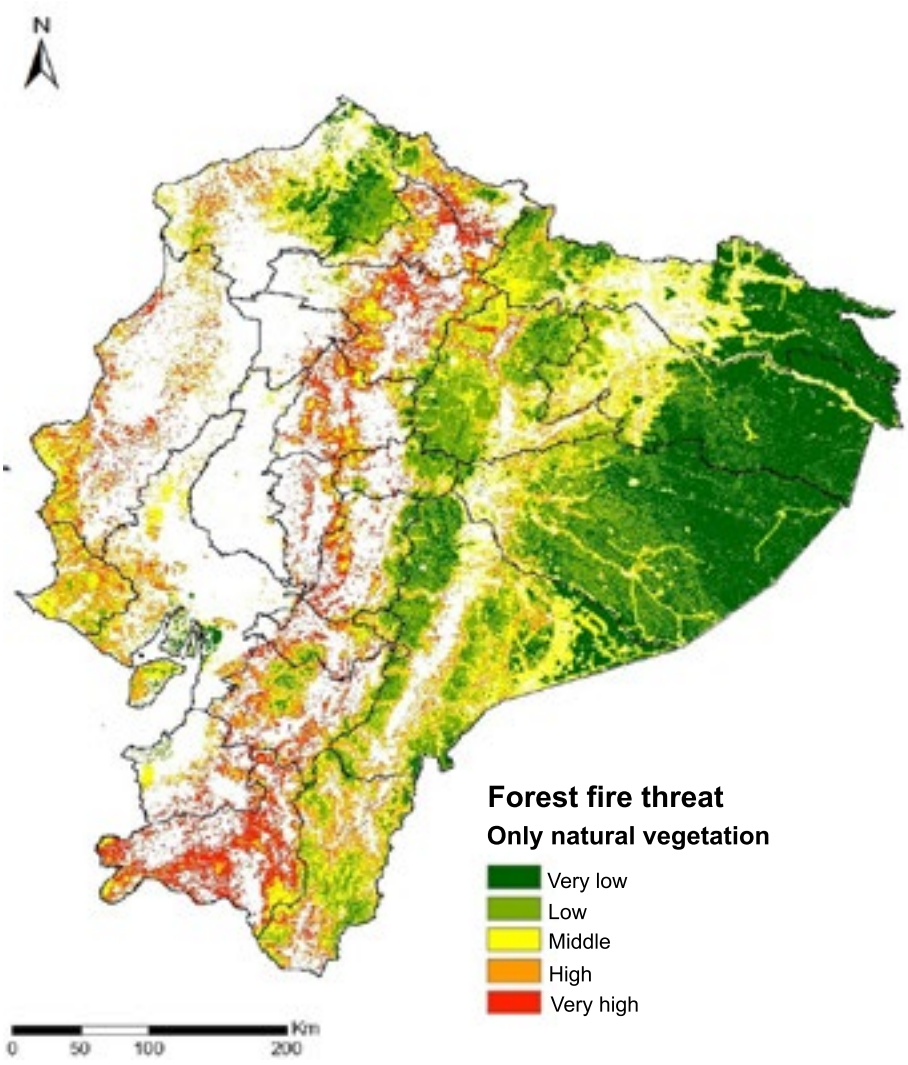

Figure 2. Level of forest fire threat across Ecuador

and strategies that aim to reduce forest fires, using a broader approach with IFM as its basis. IFM in Ecuador is defined as "the set of technical decisions and strategic actions available for the protection, conservation and sustainable use of natural heritage to prevent and mitigate the harmful effects of forest fires, integrating science and the socio-cultural dimensions with fire management techniques and technologies at multiple levels, without neglecting governance frameworks and the generation of national and local public policies, both forestry and non-forestry, for the incorporation of the IFM approach"(GOE 2019).

Actions to be implemented in the short, medium and long term aim to use fire in a legal, technically appropriate and responsible context. They are also intended to gradually replace the use of "bad" fire by promoting alternatives in agriculture (one of the sectors that causes the most forest fires), and by generating knowledge in society about this approach.

Applying integrated fire management

The Amazonía sin Fuego Programme (PASF) is the main strategy to prevent forest fires of the Ministry of Environment, Water and Ecological Transition of Ecuador (MAATE) in the country's highland and coastal regions. It involves multilateral technical cooperation that implements integrated fire management (IFM) practices and alternative fire use (AFU) measures to contribute to environmental protection and to quality of life for rural and indigenous communities. It is implemented in the provinces of Imbabura, Pichincha, Loja (highlands), and El Oro and Manabí (coast), which have the highest incidence of forest fires. The programme builds on work undertaken in Brazil (1999–2009) and Bolivia (2012–2017).

The programme does not fight forest fires, but instead proposes sustainable development alternatives to manage landscapes at risk, recognizing fire as an element of nature that must be managed. The central

Livestock producer Wilmer Enríquez from Loja Province uses fire to clear new areas for his dairy cattle. Photo: Daniel Segura

hypothesis is that the most cost-effective management of forest fires is based on prevention, and involves strengthening the capacity of national institutions and local governments to implement and coordinate actions alongside peasant and indigenous communities, many of whom are traditional and regular users of fire. ASFP is one of few initiatives in the country with a landscape vision that uses interventions based on community management, and that recognizes communities' key role in reducing uncontrolled fires.

To reduce the harmful effects of fire, the programme promotes actions based on five types of intervention. These are: (i) developing national and local planning tools for inter-institutional forest fire management; (ii) continuous fire management training at the institutional and community level; (iii) promoting alternatives to the use of fire in rural areas; (iv) environmental education and awareness-raising on forest fire prevention; and (v) building public policy and governance frameworks in IFM.

Results and lessons learned

Local and national planning tools

The Amazonía sin Fuego Programme provides planning guidelines for IFM at the local and national level, and developed methodologies were for inter-institutional technical plans for forest fire management (PIIFs) for 22 protected areas where the forest fire risk is high. Although PIIFs were initially aimed at conservation areas, they are flexible tools that can also be applied to other land at risk, such as forest plantations, farmland and urban interface areas. This is the first time that IFM has been applied in the National System of Protected Areas of Ecuador; it adds planned actions to the conservation of almost 2 million ha.

In 2018, work began on the first National Strategy for Integrated Fire Management (NSIFM), under a national committee that ensures participatory development. The National Environmental Authority is leading this dynamic process, to establish guidelines and directives to 2030, including protection and conservation actions, and climate change mitigation and adaptation measures. These will be implemented jointly by sectoral bodies and various levels of government, after formalization of this public policy instrument by executive decree expected by 2023.

Continuous training at the institutional and community level

Local and national capacities have been strengthened in multiple aspects related to fire management; these are broader than those involved in the previous focus on firefighting. The aim is to train fire managers and government officers in multiple skills, incorporating an understanding of how territorial and landscape elements influence fire prevention and suppression. However, it has proved difficult to directly link traditional knowledge of fire use by communities with an institutional apparatus dedicated to fire response.

Since 2017, the programme has trained 821 men and women, including 370 brigadistas, who participated in

14 different forest fire prevention and firefighting courses, initially taught by Brazilian experts from PREVFOGO/IBAMA. A certified skills-based IFM training model was introduced in 2020 to train Brigadistas Especialistas en Manejo Integral del Fuego (BREMIF) — specialist units in integrated fire management. Supported by the Pau Costa Foundation (Spain), The Nature Conservancy and the Fire Learning Network (USA), 491 BREMIF brigadistas undertook 11 training courses that provided the necessary skills, knowledge and abilities to organize and perform tasks, and to solve problems in a flexible and autonomous manner. They were also trained to manage fire in coordination with communities and the people who live in the landscape. Training also contributed to the use of uniform terminology, which facilitates communication and reduces ambiguity.

Promoting alternatives to the use of fire

The programme also carries out training and capacity building with peasant and indigenous communities in rural areas that goes beyond the formation of brigades. Focus areas include promoting the adoption of fire-free agricultural practices, providing necessary knowledge to farmers and extensionists about alternatives to fire, and finding a balance between the responsible use of fire based on traditional knowledge while reducing uncontrolled fires that result from poor fire management and planning.

ASFP has promoted conservation-based agricultural techniques through the establishment of ten farmer field schools. The schools incorporate principles of gender equity and equality, reciprocity, , self-management and sustainability, and promote the responsible use of fire. More than 100 farming families have been trained and 75 farm plans have been developed for implementing practices that include the preparation and application of organic fertilizers, soil conservation, agroforestry, fruit tree and silvopasture management, holistic livestock farming and ethnoveterinary techniques, among others.

Environmental education and awareness-raising

It has been particularly difficult to develop communication strategies for preventing forest fires, when earlier campaigns were based solely on the absolute prohibition of fire. Such strategies must convey that fire is an element like water or soil that must be managed. ASFP communicates this and clarifies the role of fire in the country's ecosystems and agricultural and forest landscapes, and in the urban interface.

Much effort has been made since 2017 to show the two faces of fire to the public, with the help of local and national programme partners. This includes the development of environmental educational materials and courses on forest fire prevention aimed at teachers in schools and colleges, and talks in schools, universities and communities. During the Covid-19 pandemic, the emphasis shifted to webinars, radio programmes, educational videos and use of social networks. A virtual course (Introduction to Integrated Fire Management) was developed (MAATE 2021), and a national mascot was adopted (Figure 3). Although communication takes place year-round, it intensifies in August to December.

Figure 3. The national mascot for forest fire prevention in Ecuador, a puma called Urku El Puma.

Building public policy and governance frameworks

ASFP was aware of the need for a fundamental shift in addressing forest fires from an institutional and regulatory perspective, and worked with MAATE to develop an amendment to the 2019 R-CODA regulation. The IFM approach is now legally recognized as being of public interest and is binding on all levels of government, the private sector and society. The revised regulation provides general provisions and a national and local institutional regime, and calls for the development of specific planning, management and public policy instruments related to forest fire management and IFM. The main challenge now is to ensure that the approach is implemented at different levels of government, and to adopt and internalize it at the territorial level while considering rural communities and their traditional knowledge as being part of the solution.

The ministry, with technical support from ASFP, is working on a range of normative and institutional actions in parallel, over the short, medium and long term. These include the creation of an IFM Unit within the Forestry Directorate of MAATE, enactment of the National Strategy for Integrated Fire Management in Ecuador to 2030, formation of a National Technical Committee on IFM, enactment of the National Fire Management Research Agenda 2030, development of regulations for the use and regulation of controlled and prescribed fires, development of a national programme for integrated fire management, a proposed law on integrated fire management, and development of a national fund for integrated fire management.

Conclusions

After 20 years of implementing actions in Brazil, Bolivia and now Ecuador, the *Amazonía sin Fuego* Programme has had important impacts on improving fire management. One conclusion is that although forest fires cannot be prevented entirely, their frequency and impacts can be significantly reduced through IFM. In Ecuador, there is now an increased understanding of the need to learn to live with fire, and to protect and manage landscapes at risk while improving livelihoods and the resilience of communities.

Successful approaches must address the causes of fire, incorporating sociocultural dimensions in addition to ecological attributes. Agricultural practices have traditionally depended heavily on the use of fire, which was seen as an essential tool for clearing land or preparing farmland or pastures before the rainy season. An important aspect of IFM efforts has been to involve farmers and indigenous communities as part of the solution and not just as the cause of fires. Promoting economically viable alternatives to the use of fire must also be supported by the training of fire managers, not just firefighters, in holistic, flexible and appropriate skills.

Developing effective IFM initiatives requires an institutional framework and national and local regulations. Improved decision making and effective strategies need to coordinate, make uniform, maintain and periodically publish national and local forest fire statistics aimed at managers and policy makers. However, limitations remain in monitoring, analysis and interpretation of forest fire statistics, and in knowledge management.

Globally, it is increasingly accepted that it is essential to learn to live with fire (Hernández et al. 2020). Thus, a shift in approach is needed, to accept the presence of fire and change the way that land is managed by communities. This is one of the greatest challenges facing national and local authorities. International donors and national and local actors need to be aware of this, and need to radically redirect their investments in forest fires from emergency responses and firefighting to prevention and integrated management.

Fire brigade trainees after an inter-institutional course on forest fire prevention, Guayas Province, June 2022, supported by IBAMA from Brazil. Photo: Amazonía sin Fuego Programme

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Fighting a forest fire at night in Chiquitania. Photo: FAN

2.6

Community-based fire management in Bolivia: integrating people, knowledge and good practices

Verónica Ibarnegaray, Carlos Pinto, and Natalia Calderón

"Community-based initiatives are clearly the answer, but they need to be adopted in national policies, commitments and instruments."

Introduction

Bolivia has some of the greatest biological diversity and forest cover in the world, but is also one of the countries most threatened by deforestation and forest fires. This threat is closely related to accelerated land-use change for agricultural expansion, increasingly harsh dry seasons and climate change.

Historically, the country has experienced large fire events coinciding with years of severe drought, such as in 2004, 2010, 2016 and 2019. Over the past 20 years, the annual area burned has averaged around 3.7 million hectares (ha), with an all-time high of nearly 10 million ha in 2010. In 2019 nearly 6 million ha were affected by fires across the country. Almost two-thirds of the burned areas comprise non-forest cover such as grasslands, shrublands and farmland, while one-third is forest, mostly Chiquitania and Amazonian forest types in Santa Cruz Department (FAN 2019; FAN and WCS 2021).

Agricultural burning in the Chiquitania landscape during the forest fire season. Photo: FAN

The main causes of fires in Bolivia are associated with agriculture and livestock farming, by both small and large producers. In indigenous communities, the use of fire is mainly related to clearing small productive plots and renewing fallow land, and in livestock activities and hunting, where it is a traditional practice that incorporates knowledge of local conditions. Fire is also widely used in large-scale livestock farming for pasture renewal and pest control, and in mechanized commercial agriculture to clear large tracts of land, which in many cases can cause forest fires. This is compounded by the increasing pressure of human settlements on forested areas, by regulations and development plans that favour land conversion for agriculture, and by the impacts of climate change.

Fire has always been part of the dynamics of Bolivia's forest landscapes. However, the increasing frequency and intensity of large fires is threatening the sustainability of ecosystems and the livelihoods of vulnerable communities, mainly in the Chiquitania region of Santa Cruz Department. This area has the largest and one of the most biodiverse tropical dry forests in the world, one with historical and cultural importance. Due to its transitional location between the tropical forests of the Amazon, the Gran Chaco and the Pantanal, the forest in the region is fundamentally important for maintaining ecosystem connectivity. The region connects almost 12 million ha of protected areas and conservation spaces with great value to humanity. In recent decades, however, there has been an accelerated change in land use for agricultural and livestock expansion and in new settlements, both of which are leading to increased deforestation and burning.

A holistic approach to forest fire management

In Bolivia, as in other countries in the region, a reactive approach to fire still predominates. It focuses on the negative aspects of fire, with policies aimed primarily at firefighting and suppression, and with coercive and punitive legal measures. However, the effectiveness of such approaches has been very limited for several reasons. These include a lack of knowledge of the social and ecological context in which fires occur, a lack of control and participation in decision making at the local community level, and the fact that implementation is subject to the limited capacity and resources of relevant government institutions (Ibarnegaray et al. 2014).

Over the last decade, the Fundación Amigos de la Naturaleza (FAN) has been taking a holistic approach to fire management as a nature-based, community solution to reduce risks and improve the resilience of vulnerable ecosystems and communities. Community-based fire management incorporates local participation as its basis (FAO 2011). The approach considers and integrates ecological, cultural, socioeconomic and technical aspects in strategies and practices for the prevention, use of fire, and control of forest fires. It includes the active participation of a variety of local actors, including public, private and non-governmental institutions working in land management.

Community fire-management programmes

FAN's pilot Community Fire Management Programme started in 2011, with the goal of climate change adaptation and forest fire risk reduction for communities and protected areas in southeastern Chiquitania. It was one of the winning proposals in the World Bank's global Climate Change Adaptation Development Marketplace competition in 2009. Its innovative and participatory approach aims to integrate monitoring and early-warning tools in fire management, with the active involvement of local communities.

FAN implemented this initiative for four years, working with 36 indigenous and peasant communities and three Mennonite colonies around protected areas in Laguna Concepción, Santa Cruz la Vieja and Tucabaca, in the municipalities of Pailón, San José de Chiquitos and Roboré in Santa Cruz Department. Between 2013 and 2018, the initiative was replicated in the northern Amazon region with support from the MacArthur Foundation, involving a further 15 communities in the municipalities of Riberalta (Beni) and Puerto Gonzalo Moreno (Pando). In 2018, FAN resumed activities in southeastern Chiquitania, with the European Union (EU)-supported ECCOS project. Since 2020, FAN has expanded its interventions to northern Chiquitania, in 10 communities in Concepción, San Ignacio de Velasco and Lomerío, with support from GIZ, and in the Bolivian Pantanal, supporting ANMI San Matías and Otuquis protected areas, in collaboration with WWF.

Over the last 10 years, FAN has consolidated its fire management actions into a strategic programme. Through the programme it promotes the development of research, tools and capacities to improve forest fire management practices and policies in Bolivia, with the aim of contributing to the resilience of vulnerable ecosystems and communities. FAN is currently working with 30 indigenous and peasant communities, local governments, social organizations and protected areas in the Chiquitania and the Pantanal, through various projects co-funded by international cooperation agencies of the EU and the USA.

Preparing communities to live with fire

Work with communities is oriented to local efforts to prevent and prepare for the risks of forest fires. Through training, technical assistance and participatory planning, FAN supports improved fire management practices, including monitoring of fire risks, planning and execution of controlled burns, early warning measures, and community-based first response.

Participatory monitoring

Communities actively participate in management and monitoring, supported by geospatial tools and information and communication technologies. Through participatory mapping exercises using high-resolution drone and satellite imagery, local people study and analyze their territory, establishing a zoning system for sites of great importance to conservation, protection

Forest fire in a Chiquitania forest. Photo: FAN

Prescribed burning for fuel reduction in grasslands in the Tucabaca protected area. Photo: FAN

and production. They also assess fire risks in order to improve land-use and fire management planning and management in a way that considers their livelihoods. Information on land use, production systems, fire-use practices and fire risks is recorded through the use of smart phones and mobile applications. Each community in the programme's pilot areas has dedicated fire management delegates who are trained and equipped to register georeferenced field data in digital formats designed for this purpose. They also monitor data and coordinate with community members to inform and support decisions and action planning related to land use and risk reduction. In this way, communities are provided with information and monitoring tools to guide the management of their territory in a more efficient and sustainable way.

Controlled-burning calendars

Recording information on productive practices and fire use allows communities to plan and coordinate the execution of agricultural burns through developing controlled-burning calendars. They also receive training and participate in exchanges of technical and traditional knowledge on the application of controlled-burning techniques, and on the legal procedures for complying with regulations related to the use of fire and land. Burning schedules are planned in a participatory and consensual manner by community members and are posted in conspicuous places. This facilitates monitoring and community coordination of the execution of burns under controlled conditions, which includes safety measures to reduce the risk of a burn turning into a forest fire.

Early warning

The communities have established early-warning measures to help address fire risks. They include measuring, monitoring and communicating weather conditions through portable meteorological instruments and warning signs installed in strategic locations. Daily measurements taken by community delegates help determine the level of fire danger and alert the community when people need to take preventive measures to reduce risks, such as prohibiting burning on high-risk days.

First-response brigades

Local first response is crucial to preventing the spread of fires. FAN has trained and equipped first-response brigades in more than 50 communities in the Chiquitania and the Bolivian Amazon. These brigades provide rapid response and support in fighting and extinguishing forest fires, and their knowledge of the territory is key to the success of the operations.

Strengthening institutions that manage forest fire risk

Protected areas and municipalities face major challenges in managing risk and fires; they have few resources and limited technical and logistical capacities. FAN has provided technical assistance in fire monitoring and early

warning in 10 municipalities and seven protected areas, and has also facilitated access to geospatial tools and information. In addition it has strengthened response capacity through training, equipment and technical and logistical support for firefighting to park rangers, municipal technicians and local volunteer firefighting teams.

Integrated fire management plans

FAN promotes the development of integrated fire-management plans in protected areas and indigenous territories as a management tool for the conservation and protection of biodiversity and local livelihoods in the face of forest fires. This includes the organization, planning and implementation of strategic actions that integrate the ecological, social and technical aspects of fire management with a landscape vision. The first integrated fire management plans in Bolivia have been developed for the protected areas with highest fire occurrence in the Pantanal region: Otuquis National Park and Integrated Management Natural Area (ANMI) and San Matías ANMI.

This approach has also been used for the Chiquitano Indigenous Territory Monte Verde, in the framework of a collaborative process by various actors of the Indigenous Territorial Government and community authorities, as well as experts and technicians from cooperating organizations. The aim is to strengthen local management capacity and contribute to the sustainability of community livelihoods, forest conservation and ecosystem function.

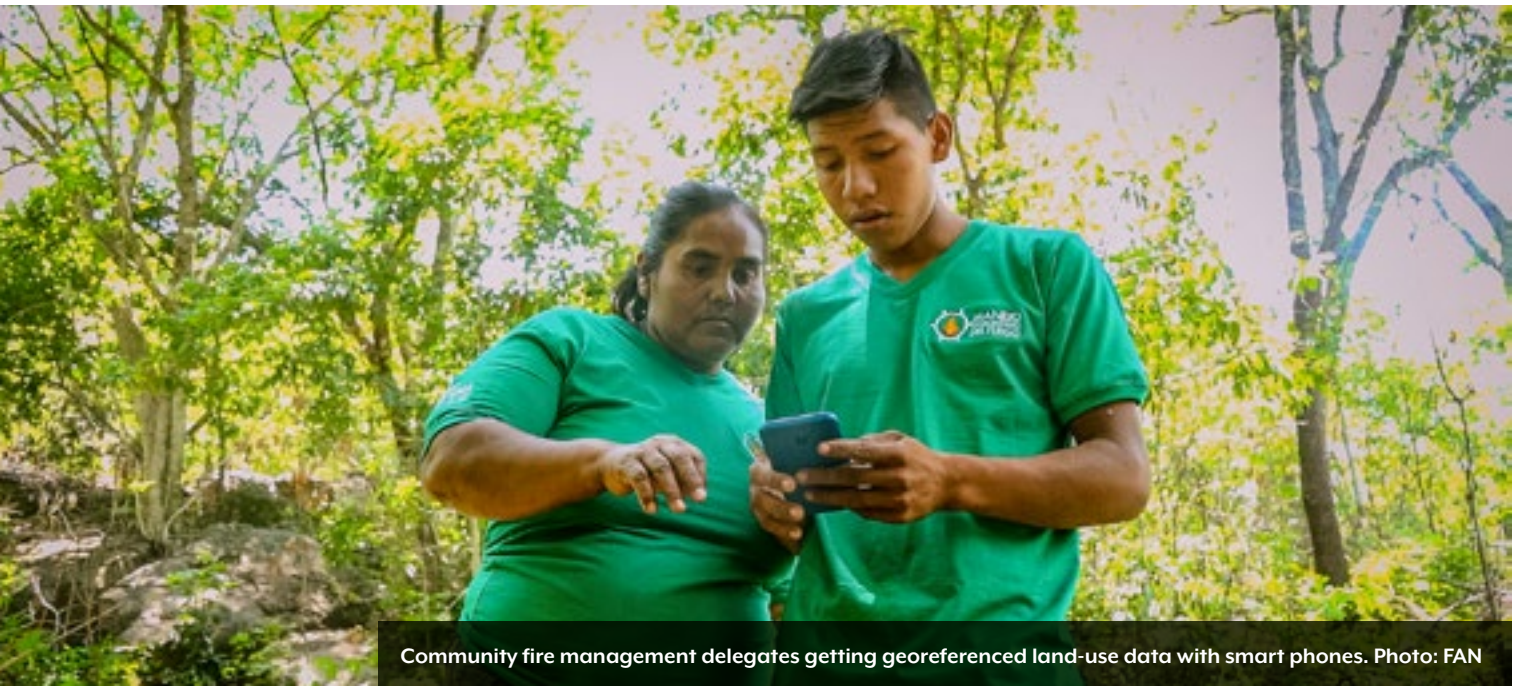
Fire ecology and prescribed burning

Research on and knowledge of the role of fire and its impacts on ecosystems support the development of landscape management strategies that are based on risk prevention and reduction. FAN has piloted prescribed burning in protected areas and nature reserves as one such strategy. The aim was to carry out low-intensity burning under specific and controlled conditions to reduce forest fuel and vegetation susceptible to burning and, consequently, to reduce the danger of fire spreading to sites with high biodiversity. This measure was first implemented in 2014 in the Tucabaca Natural Heritage Conservation Unit and protected area, and has been replicated by the Governorate of Santa Cruz within its departmental fire management programme.

Monitoring of forest fire risk

FAN has developed a forest fire risk-monitoring and early warning system called SATRIFO (Sistema de monitoreo y alerta temprana del riesgo de incendios forestales). This generates and disseminates information and geospatial tools to support and guide fire-management strategies and actions with a regional and national scope, and contributes to the various stages of fire risk management. Information includes fire risk analysis and forecasts that are based on a model that combines climatic and environmental variables. This allows users to generate

Developing a communal controlled-burning calendar. Photo: Stephen Reichle/FAN



Community fire management delegates getting georeferenced land-use data with smart phones. Photo: FAN

daily fire risk maps for the whole country, which in turn supports fire prevention and early warning. The system also provides data for monitoring of prescribed burns and active fires in order to determine response actions, and to evaluate the severity of fires and the damage to burned areas to guide restoration and management strategies. The information is available on an interactive web portal map and the SATRIFO mobile app to facilitate consultation, download and analysis. It includes dynamic and interactive mapping tools, reports and customized alerts. In more than 10 years of operation, SATRIFO has positioned itself as a source of information at the national and international level, through which it has supported the strengthening of institutional capacities for monitoring forest fires in Bolivia.

Information and social awareness

Exchange of information about and experiences in fires and fire management is fundamental to raising awareness and to involving society as a whole in the search for solutions that generate positive social change. FAN has developed communication materials for a range of audiences, and has promoted discussions among the scientific and academic community, authorities and civil society to broaden and improve the scope of its interventions.

Conclusions

Integrated fire management requires joint and coordinated efforts between government, civil society and local communities. Although FAN's initiatives have succeeded in achieving participation and collaboration by a range of actors — from the community to regional and national levels — this coordination is weakened and influenced by the complex sociopolitical forces in Bolivia.

Local communities are assuming an active and responsible role in fire management. However, stronger partnerships and technical assistance are still required to consolidate good practices, mainly those related to the use of and access to information and communication technologies. This presents an opportunity to target digital inclusion policies that provide incentives to local communities to strengthen early warning and risk-reduction mechanisms.

Forest fires have garnered a great deal of media attention in the wake of the 2019 fires, which have worsened the social rejection of the use of fire and everything related to fire as a land-management tool. This makes it even more difficult to argue for fire's usefulness in conservation purposes. The development of prescribed burning has great potential, but many challenges and barriers need to be overcome in order to demonstrate its effectiveness and benefits so that it can be recognized and incorporated as a good practice within strategies and plans for conservation and risk management.

There is still a long way to go to achieve a real transformation in the way that fires are understood and managed in Bolivia, so that policies that address land management and fire management have a holistic

and landscape-level vision. The sustainability of good practices and community fire-management initiatives will depend to a large extent on their recognition by and appropriation within governance structures and mechanisms, from the local to the national level.

The interactions between climate change, ecosystems (including their biodiversity) and human society are becoming increasingly evident and at the same time more complex and more difficult to manage. While community-based fire management initiatives offer the opportunity to move towards the development of synergistic strategies for natural resource management and conservation, risk management and climate resilience, these strategies have not yet been incorporated into the relevant commitments, policies and instruments.

Enabling conditions are key to implementing, accelerating and sustaining integrated forest fire management in Bolivia. These include political commitment and follow-up, institutional frameworks, policies and instruments with clear goals and priorities, increased knowledge of impacts and solutions, mobilization of and access to adequate financial resources, monitoring and evaluation, and inclusive governance processes, all of which are still in an incipient state in Bolivia.

Acknowledgements

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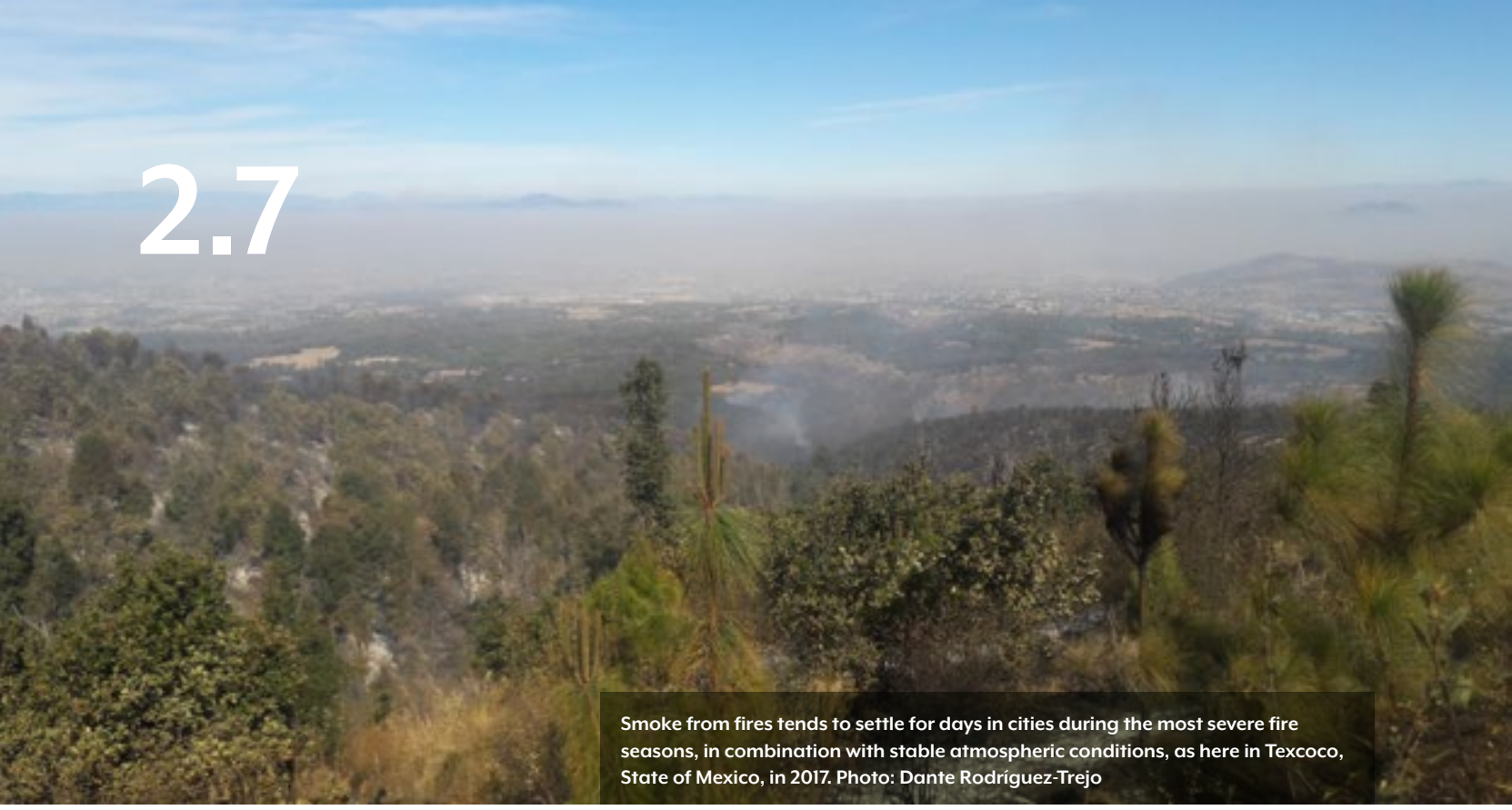

Smoke from fires tends to settle for days in cities during the most severe fire seasons, in combination with stable atmospheric conditions, as here in Texcoco, State of Mexico, in 2017. Photo: Dante Rodríguez-Trejo

Towards integrated fire management in Mexico's Megalopolis region: a diagnosis

Dante Arturo Rodríguez-Trejo, Laura Patricia Ponce-Calderón, Hubert Tchikoué, Roberto Martínez-Domínguez, Pedro Martínez-Muñoz, and Jorge Alberto Pulido-Luna

"Cultural fire-use practices have been nurtured over time, shaping the landscape and maintaining fire-dependent ecosystems."

Introduction

Between 2011 and 2020, there were an average of 3,184 wildfires per year in the Megalopolis region around Mexico City (see Figure 1). This comprised more than 40% of all the reported fires in the country, in only 5% of the national territory. In April 2019, Mexico City was immersed in wildfire smoke, leading to concerted action towards improved fire management, and this presents results from the initial diagnosis.

The region covers almost 10 million hectares and includes seven states: Mexico City, the State of Mexico, Morelos, Tlaxcala, Puebla, Hidalgo and Querétaro. The region has a very diverse environment, including hot dry, hot humid and hot sub-humid climates, and temperate and cold climates at high altitudes that can exceed 5,000 metres. There is a correspondingly wide variety of vegetation types and wildlife, with several endangered species under protection in 28 federally protected natural areas. The

region also has a high population density, with a rich cultural diversity among the large rural and indigenous populations.

Three-quarters of wildfires affect pine- and oak-dominated forests, and the main fire season is from January to May. Almost half of all fires in the Megalopolis were caused by agricultural activities (45%), with 750 fires (24%) reported in protected natural areas. Although the number of fires is decreasing, the total affected area is increasing. The mean area per fire is still very small, however, at only 7.75 hectares (ha), which is one of the smallest in the country. Almost all fires are less than 50 ha.

From 2011 to 2020, 19 agencies in the Megalopolis region contributed a total of 552,509 person-days for fire suppression, compared to an annual average in other Mexican regions of 61,390 person-days. The main contributors of labour for fire control include the state governments (37%), followed by volunteers (19%), and the National Forestry Commission (*Comisión Nacional Forestal*, or CONAFOR) (17%). Other support was provided by municipal governments, the Mexico City government (11%) and land owners (10%). Firefighting efficiency indicators in the region are outstanding, compared to national averages: the mean detection time is 14 minutes (29% of the national average); the mean fire control arrival time is 65 minutes (52%); and the fire duration time is 7 hours and 23 minutes (44%). The estimated budget for firefighting in the region was USD 281 per fire.

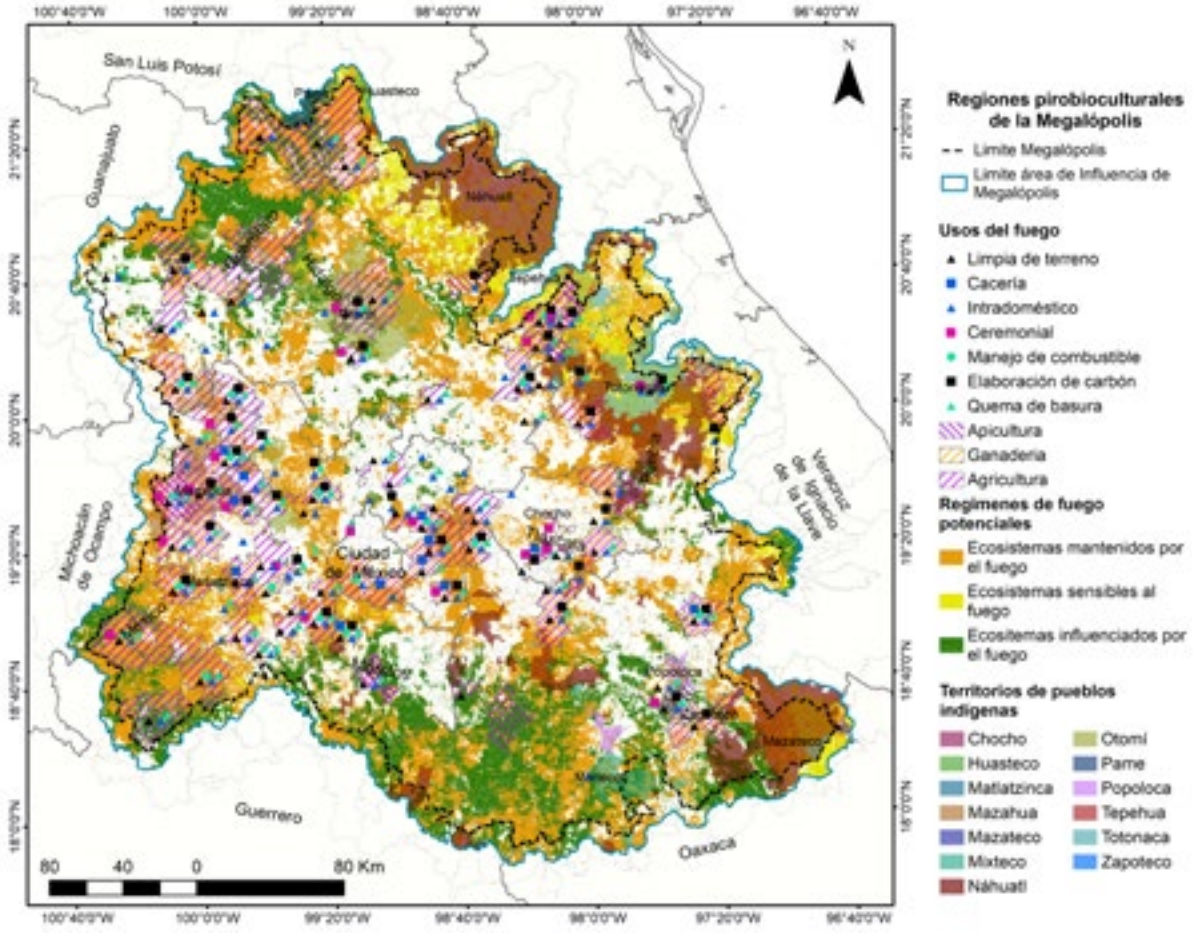

Figure 1. Pyrobiocultural map of the Megalopolis region, including relationships between vegetation and fire, uses of fire, and territories of indigenous communities. Source: UACh-CAMe (2021)

Fire prevention and firefighting

Most forest fire protection is coordinated by state and national fire management programmes, with clear objectives, strategies and actions. However, these programmes are based on suppression, and include only incipient and limited activities with a social or ecological emphasis. The general objective is to reduce

Controlled fire behaviour during a prescribed burn in a *Pinus hartwegii* (Hartweg's pine, or pino de las alturas) forest, south of Mexico City. Photo: Dante Rodríguez-Trejo

the deterioration of forest ecosystems caused by altered fire regimes, but there is no specific fire management plan or objective for the region. Emphasis is placed on institutional coordination, implementation plans and effective use of resources. Each state has a fire management committee (*Comité Estatal de Manejo del Fuego*) or committee for forest fire protection (*Comité Estatal de Protección contra Incendios Forestales)*, an operational technical group (*Grupo Técnico Operativo*), and an incident management team (*Equipo Estatal de Manejo de Incidentes*) to deal with large wildfires. States also have fire management centres. Coordination and mutual support mechanisms between federal and local government are established through annual agreements.

In the Megalopolis region, there are 499 firefighting brigades with 5,043 members, more than 40% of whom are in Mexico City (Table 1). Most brigade staff are provided by forest owners and communities, alongside government-supported rural brigade programmes, CONAFOR and the National Commission of Natural Protected Areas (*Comisión Nacional de Áreas Naturales Protegidas*, CONANP). The CONAFOR and CONANP brigades are in the minority, but bring more experience and technical and operational guidance, along with state organizations such as the Natural Resources and Rural Development Commission (*Comisión de Recursos Naturales y Desarrollo Rural, Ciudad de México)* and *Protectora de Bosques del Estado de México* (PROBOSQUE).

Table 1. Number of fire brigades and brigade members by state

State	No. of brigades	No. of brigade members
Mexico City	211	2,197
State of Mexico	108	1,102
Puebla	56	569
Querétaro	42	384
Hidalgo	38	328
Morelos	30	314
Tlaxcala	14	149
Total	499	5,043

The region has 552 lookout towers, 1,546 firefighting camps and 22 engines, as well as radio communication resources, provided mostly by state governments, CONAFOR and municipalities. In terms of training, 354 people attended eight courses on various topics; 10% were women. The region's total spending for fire response in the ten-year period (2011–20) was US$160.9 million: the most was spent in 2014 (US$33.2 million), and the least in 2021 (US$3.7 million).

Ecological components

Fuel loads and fire behaviour. Given its diverse vegetation and disturbances, the region has a range of fuel models, from short grass in dry shrublands to tall grass in cool-to-temperate, tropical and subtropical grasslands, and understorey vegetation in dense or open forests. Fuel loads range from 0.5 to 92 tonnes per hectare. In surface fires, which are the most common, with low fuel loads, flat ground and no wind, fires advance at less than 1 m/min, with flame lengths less than 0.5 m. In contrast, with high loads of light fuels such as tall grass and on steep slopes with fast updrafts, fires can advance at 200–400 m/min, with flame lengths of 8 m. During crown fires, flame lengths can exceed 15 m.

Relationship between vegetation and fire. Vegetation types maintained by fire prevail in the region. Tree species adapt by having thick bark, being self-pruning, being serotinous (requiring the heat of a fire to release their seeds), and being able to resprout from base and crown. Grasses in all ecological regions resprout rapidly, and many flower post-fire (Rodríguez-Trejo 2014). Alterations in fire regimes (e.g., increased fire frequency or fire exclusion, both of which can ultimately lead to catastrophic wildfires) can facilitate the spread of undesirable species, both native and invasive, including fire-favoured ferns, which are very difficult to control. In pine and oak forests, such alterations also often favour the expansion of native oak shrub thickets. More frequent fires degrade forests into grasslands. Periodic fires favour pine and oak forests; very frequent fires favour grasslands.

Ecological models for successional trajectories in each vegetation type show a higher frequency of fire in early successional stages, followed by a progressive reduction of fire occurrence. Cloud forests, for example, may start as grassland, then include pine forest and oak forest, then incorporate liquidambar, before becoming a true mountain mesophyll (Rodríguez-Trejo, 2014, Ponce-Calderón et al. 2021.

Fire regimes. Fire regimes reflect the pattern, frequency, intensity, severity, time of year and extent of wildfires. Excessive fire often degrades any type of vegetation. Fire exclusion leads to fuel accumulating and favours catastrophic wildfires, a situation that is also affected by climate change. Natural fire regimes maintain fire-related vegetation. Fire regimes with frequent (5 to 10 years) and surface fires of moderate intensity and severity occur in pine and oak forests and their combinations, xerophytic shrublands and grasslands. In dry shrublands, surface and passive crown fires occur in grasslands dominated by *Dasylirion lucidum* (Rodríguez-Trejo et al. 2019). Some cool temperate forests have a mixed fire regime, with relatively frequent surface fires and crown fires and high tree mortality every few decades. In tropical vegetation, most tree species in tropical rainforests and mesophyll forests are fire sensitive, post-fire mortality is high, and secondary succession may take many decades.

Environmental effects. Among the positive effects in ecosystems maintained by controlled fire are the reduction of fuel load and fire danger, more vegetation

Burning crop residues is a common practice in the region. Photo: Dante Rodríguez-Trejo

types, ecosystem stability, environmental heterogeneity, species diversity and wildlife habitat. In fire-exclusion areas negative environmental effects arise because fuels accumulate; together with the effects of climate change, this increases the occurrence of larger wildfires, danger for firefighters, fire control costs, fire duration and tree mortality (67–100% in the most affected areas). This in turn leads to erosion, wildlife mortality and emissions of pollutants and greenhouse gases. High recurrence of low-severity human-caused fires also degrades ecosystems, particularly if they are overgrazed. Both situations lead to smoke accumulating for long periods in the Megalopolis.

Cultural fire knowledge

This article incorporates a sociocultural component to understand and analyze cultural knowledge of the use of fire in the region, in order to make apparent people's experiences with it. The Megalopolis includes 1,574 urban and 20,157 rural or indigenous localities; many of the latter consider the use of fire to be indispensable. This arises from their view of fire as elemental in their way of life, and as an intergenerational legacy that is represented in social practices and productive processes (Ponce-Calderón et al. 2020).

A crown fire in a Mexican cedar (*Cupressus lusitanica*) plantation, State of Mexico. This species has a low crown and very flammable foliage, both of which facilitate crown fires. Photo: Dante Rodríguez-Trejo

The use of fire contributes to well-being in many ways. Cultural fire-use practices have been nurtured over time, shaping the landscape and maintaining fire-dependent ecosystems. For example, communities who carry out agricultural burns consider weather, wind, terrain and the starting point of the burn, among other factors, in order to reduce the risk of the fire spreading. These links between culture and fire in the territory have created pyrobiocultural territories, based on cultural groups, fire use and fire-vegetation relationships.

The role of grandparents is crucial. Elders safeguard traditions that are maintained and transmitted to new generations. This begins early, when children accompany their parents to their plot of land to carry out cultural work. There is no certainty that this fire knowledge can be preserved, however (Ponce-Calderón et al. 2020).

And even within indigenous communities, there are conflicting views of the benefits of fire. This may be due to intergenerational gaps, migration, modernization of the countryside, use of agrochemicals, and lack of interest in rural activities. All of these factors can lead to a loss of cultural knowledge, including use of fire. The denial, exclusion and loss of these practices affect ways of life, and fire prohibition can lead to their gradual disappearance.

It is not just about whether and how indigenous or rural communities use fire, it is a question of whether governments should intervene in a cultural system where fire plays a crucial role in domestic, productive, ceremonial and ritualistic spheres. Fire is a cultural approach that historically has allowed people to live sustainably.

Each indigenous community maintains cultural practices and claims territorial rights through traditional uses and customs, and alternative and organizational approaches to fire management need to be generated to give legitimacy to these uses (Rodríguez et al. 2015). The use of fire by communities is not a direct cause of wildfires, and prohibiting its use ignores the fact that fire will continue to be used where people's right to territoriality and self-determination is paramount. Also, banning the use of fire can have unanticipated sociological and ecological consequences.

By recognizing pyrobiocultural diversity, it will be easier for governments to establish an intercultural dialogue, and to make fire management proposals that include the knowledge, experience and needs of the people who live in the area. To safeguard the knowledge of fire users

Large and complex wildfires, like this one near the Tláloc volcano in 2017 that affected more than 2,500 ha, can occur during very dry periods. Photo: Dante Rodríguez-Trejo

and others the approach must follow national laws, including the regulation on the use of fire (*Norma Oficial Mexicana NOM-015-SEMARNAT/SAGARPA-2007*). It must also include technical considerations and methods of use of fire in forests and agricultural land, as well as internal community regulations, and a participatory approach to fire management is needed (Bilbao et al. 2019).

Interventionist programmes often fail because they do not make sense in communities' ways of life. A socio-cultural facilitator is needed, whose objective is to energize the people in the community to organize themselves around shared problems.

Land and common areas are spaces where people have the right to and the capacity for protecting the environment, and for indigenous communities to live with dignity. Fire users are heirs to learning that has been passed down through generations, a deep knowledge that can be seen as a cultural heritage. A central role must be given to communities and local organizations, because their link with fire is part of their social practices and symbolic constructs.

Legal framework

The Constitution of Mexico states that "every person has the right to a healthy environment for their development and wellbeing" (Article 4, Paragraph 5), and furthermore, that government will guarantee respect for this right and apply laws that protect against environmental damage. Three levels of government — national, state and municipal — have legislation built on this legal provision.

A complex set of treaties, agreements, statutes, laws and regulations regulates forest ecosystems and fire, and determines the involvement of institutions and other actors at each governance level. Only one measure, however, the national General Law on Sustainable Forest Development (enacted in 2018, consolidated in 2021), defines the concept of fire management; it also recognizes the role of fire in ecosystems. In the Megalopolis, the legal framework for forest resources, fire and human activities is managed under seven local political constitutions, nine codes and 56 laws, which are generally structured under the same criteria as in the federal regulations. This means that the basis of fire management is, in essence, based on fire suppression and on the presumption that fire has only negative effects, and does not consider the positive ecological and social roles of fire in ecosystems.

These instruments establish that, for the protection of natural resources against fire, there must be fire prevention and firefighting programmes, with the coordinated participation of institutions from the three levels of government as well as smallholder farmers, local communities, Indigenous people, civil society organizations, land and forest owners, and society in general.

Recommendations

Achieving a balance between reducing unwanted fires and incorporating prescribed and controlled (cultural) burning should enhance all the positive effects of fire. Efforts should in particular reduce the danger of large wildfires, maintain the ecosystem and reduce the negative effects of fire, including emissions of pollutants and greenhouse gases (Rodriguez-Trejo 2000; 2014).

In addition, legal and regulatory instruments should respect the right of rural communities and indigenous peoples to use fire in a way that is based on their cultural knowledge (Ponce-Calderón et al. 2021). Legal instruments that consider fire management should be developed in an integral and intercultural manner, based on social science and ecology, and should support practices that maintain the role of fire in socio-ecosystems. In order to do this, the inclusion and effective participation of indigenous communities — together with the institutions responsible for implementing fire management policies and actions — are essential.

Technical capacities, scientific information, cultural knowledge and basic regulations that allow for effective integrated fire management exist in the region. However, improved coordination is required among public officials and technicians from the various fire, conservation and environmental management agencies of the federal government, states and municipalities, and with indigenous and rural communities and researchers. The aim should be to co-develop a strategy for fire management programmes that incorporates cultural and ecological approaches to fire.

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Community firefighters controlling a forest fire in Palmira community, Lomerío. Photo: Territorial Technical Unit of CICOL

2.8

Fire management in indigenous territories in Bolivia

Anacleto Peña Supayabe, Laurenz Romero, Juan Pablo Baldiviezo, and Nataly Ascarrunz

"Fire is life, since without it we would be nothing. Fire is the companion of our people."

Introduction

The size of the area affected by wildfires in Bolivia has reached historic levels in the last few years. The department of Santa Cruz experienced its greatest environmental crisis, following a prolonged drought and high temperatures. Catastrophic wildfires burned through 3.7 million ha in the country in 2019 and 2.2 million ha in 2020 (FCBC 2020, FAN 2021). These events severely affected the indigenous territory of Lomerío; more than half of its total area was burned in both 2019 and 2020. These fires originated in the border areas, and devastated communities, pastures and agricultural land as well as forests within the Indigenous Territory of Lomerío.

The knowledge and traditions of indigenous communities in lowland Bolivia define a way of life that sustainably uses and manages natural resources in harmony with nature, and contributes to the conservation of land and forests. The use of fire in their worldview is in balance with the environment,

Forest fire in Lomerío, 2020. Photo: Territorial Technical Unit of CICOL

and is key to the well-being of their communities. This is in stark contrast to agro-industrial models, which are currently the greatest threat to the environment, and are leading to the destruction of large areas of forest in the country, the region and the world.

This article presents an analysis of the aspects that guide the management of risks associated with wildfires in territories governed by indigenous communities in Bolivia, and the crucial factors that contribute to the formation of responsive actions. These aspects include (i) indigenous worldviews regarding natural resources and the use of fire; (ii) strengthening of indigenous institutions for risk management; and (iii) autonomous, participatory and democratic indigenous community governance models; e.g., Community Territorial Management Plans (CICOL/ Fundación Tierra 2019).

It also examines the advances, limitations and challenges in addressing wildfire threats at the level of indigenous territories. Its case study is the Indigenous Territory of Lomerío of the Monkoxi People, and the land management approach promoted by the indigenous territorial government, the Central Indígena de Comunidades Originarias de Lomerío (CICOL).

Re-emergence of indigenous land rights

The indigenous peoples of Bolivia, in claiming their rights to ancestral territories, have been able to influence reform processes for the distribution and tenure of land. In 1996, they won the legal right to own their territories under the country's *Agrarian Reform Law*. This includes indigenous peasant territories, or TIOCs (Territorios Indigenas Originarios Campesinos), which the law defines as "geographical spaces that constitute the territories of indigenous and original peoples and communities, to which they have traditionally had access and where they maintain and develop their own forms of economic, social and cultural organization, so as to ensure their survival and development." This constitutes collective ownership that is inalienable, indivisible, irreversible, unseizable and imprescriptible. Ownership is managed by communities or associations, who are assigned the right to the exclusive use of renewable natural resources on their land. In addition, they have the right to participate in decision-making processes for non-renewable natural resources on their territorial land, the administration of which is subject to sectoral laws.

Requests for land titles by indigenous peoples since 1996 total 32 million hectares, 21 million of which were for indigenous communities in the lowlands. In 2006 alone, land titles were issued for 8.4 million ha, 6.2 million ha of which were in the Department of Santa Cruz, in favour of 31,653 indigenous people (Osuna and Lopez 2009). These indigenous territories are important in the context of forest conservation, sustainable management, and contribution to poverty reduction, food security, and climate change adaptation and mitigation.

Governance in Lomerío

The indigenous territorial government (*Central Indígena de Comunidades Originarias de Lomerío*, CICOL) was formally constituted in 1997, at the end of a process of structuring

their indigenous autonomy in the search for self-governance. The Monkoxi People adopted instruments of institutional recognition such as autonomous indigenous statutes and tools for territorial management and development. The aim was to establish a model of governance based on their world vision.

After a process that lasted 10 years, the Besiro-speaking Monkoxi People of Lomerío obtained title to their ancestral territory in 2007 — covering an area of 259,188 ha and with a population of 6,481 people — in the name of the (CICOL). It includes 29 communities in the Department of Santa Cruz, in the municipalities of San Antonio de Lomerío, Concepción and San Miguel de Velasco. The territory includes four types of land use: extensive agricultural use, agrosilvopasture, forestry and protected natural areas. The main productive activity in Lomerío is subsistence farming, followed by livestock grazing (mainly on natural silvopasture) and forestry.

CICOL assumes an institutional role to promote sustainable development actions (framed in territorial policies), and to represent the population to all government entities. It developed and validated a community territorial management plan, the Plan de Vida de la Nación Monkoxi Besiro de Lomerio, 2020–24 (CICOL/Fundación Tierra 2019), and the CICOL statutes and regulations document, The Road to Freedom (CICOL 2019a). These instruments support the fulfillment of their collective and individual rights, and reinforce the process of consolidation of their indigenous autonomy.

The Monkoxi People have profound inter-relationships with forests, natural resources and the environment, and their use of fire is based on generations of local knowledge and customs that aim to limit the risk of forest fires. However, changes in weather patterns, increasing pressure on natural resources, generational change, and the effects of agricultural expansion around the territory, have created a situation in Lomerío that requires the development of new processes and initiatives to reduce the risks of forest fires.

This led to the determination of CICOL to urgently address the severity of the situation, based on a clear understanding that wildfires were cyclical. They proceeded to develop internal procedures and mechanisms to significantly reduce wildfire risks through improved fire management.

The worldview of the Monkoxi People on natural resources and fire

The Monkoxi People of Lomerío have a concept of their territory as "the big house." They believe that it is more than just a geographical space; it is a place where the cultural, social, spiritual and livelihood elements that characterize their identity are present. Their worldview — of being part of a whole, and therefore of the integrality of and balance in the relationship between people and nature — promotes the responsible use and management of natural resources. These concepts were central in developing their territorial management plans, and in

Agricultural productive plot undergoing a controlled burn by the UTT CICOL. Community San Simón, Lomerío, 2020. Photo: IBIF

Environmental monitors from UTT CICOL verifying the deforested area, Lomerío. Photo: IBIF

actions aimed at mitigating and preventing wildfires, as well as those related to fire management.

Fire was described by the First Great Cacique (chieftain) Anacleto Peña as central to existence. "*Fire is life, since without it we would be nothing. Fire is the companion of our people — in the house, for cooking and heating), in the hunt, to light charutos and make campfires to scare away the tiger and the evil spirits of the mountain*" (Anacleto Peña 2021). The use and responsible management of fire is an integral part of sustaining the livelihoods of the Monkoxi People, and forms the backbone of the value they place on their ancestral knowledge and practices. This ancestral tradition is complemented by modern techniques and technology to develop territorial policies for reducing fire risk and implementing procedures for fire management across their communities.

Indigenous governance equals improved management of fire risk

This governance model is based on the traditional organization and customs of the Monkoxi people, and provides legitimacy for the decision-making process. Based on participatory democracy, it is implemented in various mechanisms related to decision-making processes, and in institutionalized consensus. These mechanisms are defined in statutes and regulations, which describe the organizational structure of government and set out responsibilities and procedures that facilitate inclusive deliberation for decision making.

Article 15 of CICOL's statutes and regulations (CICOL 2019a) defines four levels of participation:

- Ordinary general assemblies are the highest authority that define institutional, organic, political, economic, social and cultural life.
- Extraordinary general assemblies are held to deal with emergencies that cannot be resolved by the Board of Directors, and may be convened at the request of one or more of its 29 affiliated communities, or by the Board of Directors or the Council of Elders.
- Zonal assemblies are the highest representative authority at the community level.
- Communal assemblies are the highest representative authority at the communal level.

These assemblies provide feedback to each other regarding the implementation of policies and strategies for integrated territorial management. Strategic agreements that arise from general assemblies define the development approach of the Monkoxi People and approve operational management instruments from the local level (communal plans) to the implementation of a collective vision, or Plan de vida, for the territory as a whole (CICOL/Fundación Tierra 2019).

Application of this governance model has tackled the risks and uncertainties related to wildfires, and ensured that fire management within Lomerío incorporates and maintains ancestral knowledge while also adopting innovations and new technologies. Strategic policies and

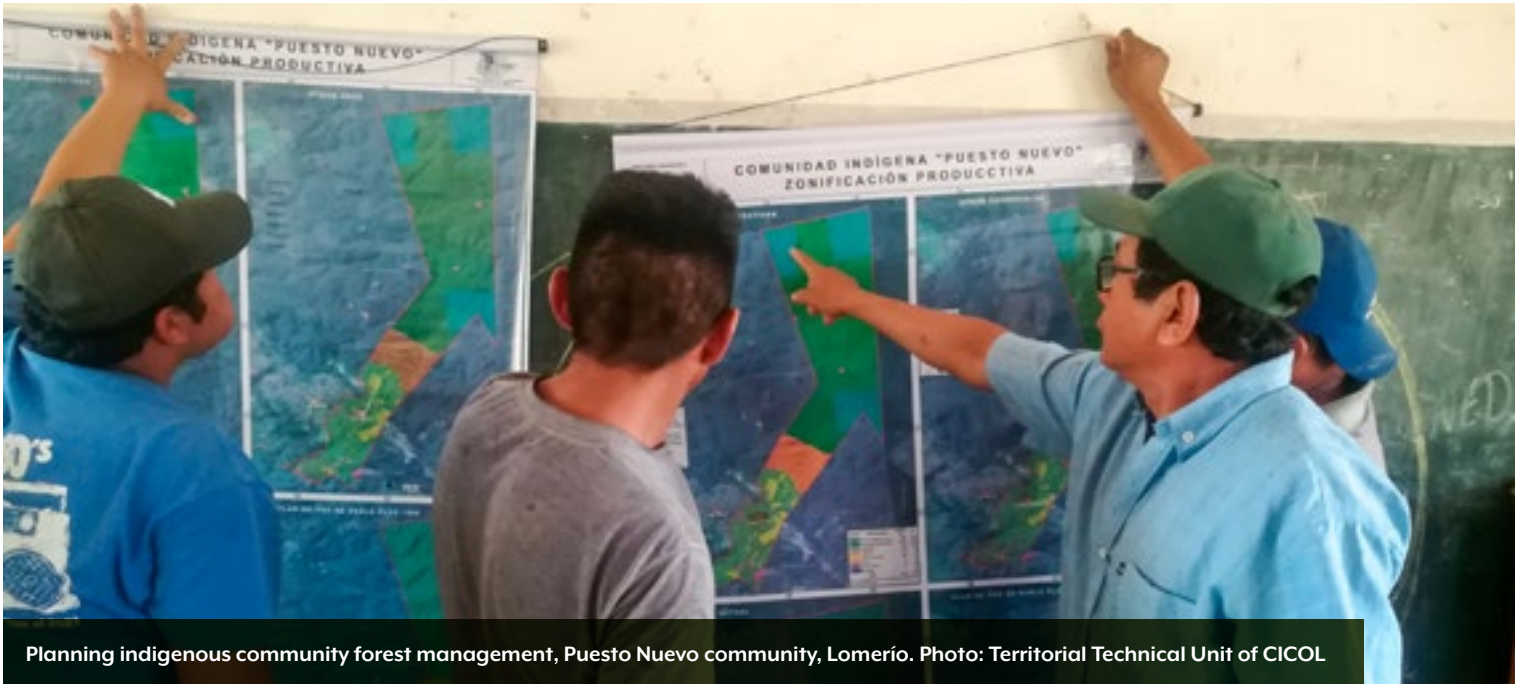
guidelines for monitoring wildfire risks were developed and established through consensus between all 29 Monkoxi communities in the territory. Additionally, rules and procedures for fire management were developed, approved and implemented as best practices for conserving natural resources and ensuring livelihoods.

The development of management tools and the implementation of specific actions have involved a variety of external institutions, including the Bolivian Institute for Forestry Research/*Instituto Boliviano de Investigación Forestal* (IBIF). Processes were governed by defined internal operational management plans, including the Monkoxi Community Territorial Management Plan (or Life Plan/*Plan de vida*), and regulations for access, use, management and protection of the land/territory and its natural resources (CICOL 2019b). Plans and regulations include scheduling and procedures for prescribed burns in areas cleared for family farming. These in turn are based on a prescribed burning protocol that is informed by monitoring natural resources, a fire management plan focused on prevention, and rapid response to and contingency measures for illegal burning and forest fires.

CICOL established a technical territorial unit to support and articulate the cooperation between various stakeholders. This was key to the development, establishment and implementation of CICOL's tools for fire monitoring and land management. The unit also implements an organizational system focused on the prevention, monitoring and control of all natural and human-induced disasters, in coordination with the chief of natural resources, brigades of environmental monitors, community forest firefighters, Monkoxi communities, and the municipality of Lomerío. Additionally, CICOL has established institutional agreements with the Bolivian Forest Service to validate the information provided by the technical territorial unit; this helps to facilitate the legal processing of complaints against illegal burning, deforestation, and the illegal extraction of natural resources.

A variety of institutions have come together to support CICOL in its management of land and natural resources. IBIF is the main provider of knowledge and experience in indigenous forest management; this drives the improvement of management skills by local actors, which in turn supports their territorial governance.

IBIF has implemented three initiatives since 2020 in response to the needs of CICOL and its communities. These initiatives have promoted a process of institutional strengthening and territorial governance associated with forests and natural resources, which is reflected in the agreements made in four aspects of governance: (i) regulation for access, use, harvest, management and protection of the land, territory and natural resources; (ii) plan for monitoring and evaluating natural resources; (iii) fire prevention plan and rapid response and contingency measures for controlled burning and forest fires; and (iv) burn control protocol.



Planning indigenous community forest management, Puesto Nuevo community, Lomerío. Photo: Territorial Technical Unit of CICOL

Conclusions

The governance model is based on internal processes of social cohesion that are framed by the norms and traditions of the Monkoxi people. It is a primary factor in the legitimacy of transformational change in Lomerío and in the reduced fire risk in the region. New initiatives are developed and implemented with the active participation and empowerment of Monkoxi communities.

Supporting and strengthening the legitimacy of CICOL — and the commitment to manage the Monkoxi People's territory according to their cosmovision — were key in the successful implementation of fire measures by the technical territorial unit. The partnership between IBIF and CICOL helped to build on established processes in Lomerío. This resulted in the rapid implementation of procedures for reducing risks from natural and human-caused disasters, as well as monitoring systems to improve the sustainable management of the Monkoxi People's territory.

The technical territorial unit, under the leadership of CICOL, continues to expand its capacity through specialized information studies, development of management tools (plans, regulations and procedures), and support for technical personnel. The unit develops skills and competencies, and provides technical information to inform decision making. This reinforces the institutional framework for integrated territorial management, which in turn leads to the successful implementation of a holistic fire management plan that is innovative and is tailored to the needs of the Monkoxi People.

The governance model of the Monkoxi People — and the respect for and support given to their internal processes through partnerships and collaborations — have improved their control and management of their territory. The legitimacy of CICOL's participatory approach to decision-making processes has empowered it. Additionally, the success of the technical territorial unit has helped CICOL to significantly improve their control over 300,000 ha of forested land of the Monkoxi People in the neighbouring indigenous territory of Monteverde, which now falls within their monitoring and fire management plans.

Five key aspects are identified for developing long-term responses and solutions to wildfire management in indigenous territories: (i) respecting indigenous worldviews concerning natural resources and the use of fire; (ii) strengthening local indigenous organizations; (iii) supporting governance models based on participatory community democracy; (iv) implementing innovative tools based on local knowledge; and (v) identifying and building on processes of change that are already underway.

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A burned baby lesser anteater (*Tamandua tetradactyla*).
Photo: JR Pachaly

2.9

Wildlife management in Brazilian wildfires: a One Health approach

Letícia Koproski and Paulo Rogerio Mangini

"Wild animals are very much victims of wildfires, but there are also wider impacts that require a more holistic approach."

Introduction

Despite the clear threats from wildfires to biodiversity, until recently wildlife has not been seen as a priority in fire management. In Brazil, for example, before 2000 there was no specific legislation to protect wild animals from the impacts of wildfires, nor any structured rescue programmes or response centres. At that time, it was mainly zoos and a few wildlife rehabilitation centres with specialized teams of veterinarians, biologists, etc., that filled the gap by caring for burned animals.

Recently, however, the effects of fire on fauna have been more deeply analyzed, along with an extrapolation to ecosystem and human health. In December 2021, the Food and Agriculture Organization, the World Organization for Animal Health, the World Health Organization and the United Nations Environment Programme published a statement confirming their support for the One Health concept (FAO-OIE-WHO-UNEP 2021).

Carbonized lesser anteater (*Tamandua tetradactyla*). Photo: Tiago Boscarato

This is an integrated, unifying approach that aims to sustainably balance and optimize the health of humans, domestic and wild animals, vegetation, ecosystems and the broader environment.

This concept focuses on zoonoses (diseases which can be transmitted from animals to humans) and health issues, and recognizes the interconnectivity of environmental issues. One Health deals with sector-specific topics across disciplines — including prevention, mitigation, preparedness, and response and recovery — that improve and promote health and sustainability. Increasingly, this concept is being discussed in disaster situations, including wildfires.

Wildfires can be considered a threat to health – similarly to a disease. As with diseases, wildfires cause negative impacts on humans, animals, vegetation and ecosystems, and are an ecological stress factor. Fires may also support good health, as their occurrence is in part responsible for maintaining a balance in communities of living organisms. In other words, the absence of fire does not necessarily mean that an environment is healthy, since at certain levels and intensities fire may also help to ensure a sustainable ecosystem.

Fire-fauna relationships

Wildfires affect wildlife in all ecosystems, and their effects on fauna are diverse and complex (Lyon et al. 2000). The severity of impacts varies according to factors associated with fire regimes, the vulnerability of ecosystems, and other aspects, including the time of occurrence (day/night, season), uniformity, intensity, size, periodicity and duration.

The amount and location of combustible material (fuels) as well as weather and topography determine the speed of a fire and its duration, and thus directly affect animals' ability to escape. The time of the year when a fire occurs also influences combustion and spread; this is related to the humidity of vegetation, and may determine impacts on certain animals. This includes, for example, the impacts if a fire occurs during nesting season when chicks are unable to escape, or at a time when reptiles are shedding their skins. In many regions, climate change is leading to increased fire occurrence and longer duration of droughts in early spring. These factors can have more severe impacts on fauna. Increased fire frequency and intensity are also closely related to high vegetation mortality, which reduces the availability of food, shelter and breeding/nesting sites.

People used to think that only young or sick animals or species with little ability to escape were severely affected by fire and that adult animals were only occasionally injured or killed. It was thought that mortality was limited to a relatively small part of wildlife populations, and that high numbers of dead animals were mostly associated with high-intensity events. However, in almost all cases, unbalanced fire regimes — that result from human activities in the context of climate change — severely affect all fauna. On the other hand, however, in environments with healthy burning regimes, the benefits of fire for fauna can outweigh the negative effects on an individual scale, with some species benefitting from the presence of occasional fire.

Species that inhabit environments with a history of fire occurrence have co-evolved survival adaptations. These may include keeping their distance from flames, development of dense fur or other outer coatings, reactivity in searching for shelter in safe places, adaptation to high temperatures, ability to enter a state of inactivity, and using burned areas for food and/or for breeding and rearing young (Nimmo et al. 2021).

An animal's response to fire is related to its size and displacement capabilities (ability to escape). Small mammals tend to show more exaggerated flight reactions, whereas large and medium-sized reptiles, birds and mammals show smoother movements. Small and medium-sized mammals, reptiles and amphibians can take refuge from fire in burrows in the ground, where temperature increases are relatively small, and the availability of such burrows is an important factor in

an animal's ability to survive. Larger animals with high mobility can escape along or away from the fire front, or take refuge in safer areas such as lakes and rivers.

During extreme events, individuals of some species may also show unexpected behaviour, such as the aquatic displacement of arboreal howler monkeys (*Alouatta caraya*), and the defensive behaviour of striking in the flame's direction, as seen with some snakes (e.g., urutu/*Bothrops alternatus* and *B. moojeni)*. However, the co-evolutionary adaptations developed by various species are often no longer able to provide sufficient protection, and wildfires kill or injure wild animals of all sizes. Even if a fire kills a relatively low number of animals, this can represent significant losses that could have an impact on the continued local survival of a species' population.

Mass fauna mortality and One Health risks

The need for significant change became impossible to ignore during the 2020 wildfires in South America's Pantanal biome, which provides habitat for hundreds of endangered species. One estimate indicated that almost 65 million native vertebrates and four billion invertebrates were killed that year. More than four million hectares were affected. Such mass fauna mortality events can lead to the local extinction of species that provide an important buffer against zoonotic disease emerging in humans.

High species richness and equalized abundance allow organisms to compete ecologically. This creates a dilution effect, where a high diversity of vectors that are less able to spread disease reduces the infection risk for host species, including humans. Emerging and re-emerging diseases, about 70% of which are zoonoses, reinforce the need to better understand the integrated and inconstant epidemiological relationships between animals and people, especially in unhealthy ecosystems (Daszak and Cunningham 2002). In addition, wildfires can compromise the long-term viability of species and ecosystem stability, with potential impacts on human health in the long term.

As seen with the Covid-19 pandemic, the health of humans, wildlife and ecosystems are closely related, and local health problems can become global threats. Severe acute respiratory syndrome (SARS) and Covid-19 are both caused by previously unknown coronaviruses, and their emergence and dispersion show that even well-adapted infectious agents can move from their original ecological niches and assume new pathogenic characteristics (Mangini and Silva 2007).

Nine-banded armadillo (*Dasypus novemcinctus*) carbonized in Ilha Grande National Park, Brazil. Photo: Tiago Boscarato

Another interesting example is Nipah, a virus that was first reported in Malaysia in 1998. Its emergence could be attributed to the uncontrolled use of fire to clear forests for agricultural expansion, along with other human-caused factors. Whatever the cause, the resulting landscape alteration led bats to migrate into cultivated orchards and human-inhabited areas, creating the conditions for this disease to emerge (Raval and Mehta 2020).

Emergency responses

In is only in the past few years that emergency management frameworks for wildlife and wildfires began to be implemented in Brazil, alongside similar initiatives elsewhere in Latin America, notably in Argentina and Chile (Salaberry-Pincheira and Oliva 2018;

Dead urutu (*Bothrops alternatus*) with burns inside its mouth and on its head. Photo: Leticia Koproski

A rodent (family: Cricetidae) rescued from a fire in Ilha Grande National Park, Brazil. Photo: Tiago Boscarato

Muñoz-Pedreros et al. 2020). The Brazilian effort involves the joint actions of many institutions in collaborative wildlife emergency preparedness, response and recovery. These include the Ministry of Environment, Brazilian Institute of Environment and Renewable Natural Resources, National System for Prevention and Combat of Forest Fires, state fire services, civil defence bodies, state environmental agencies, federal and state veterinary boards, veterinary rescue teams, wildlife rehabilitation centres, zoos, NGOs and universities.

Response actions have been defined, based mainly on the affected fauna group, but they need to be improved to create best-practice measures that better meet wildlife needs by considering a much broader range of factors. It is important to incorporate not only the specificities of the ecosystem and the type of fire, but also scene recognition (i.e., analyzing and identifying a location), and the necessity for and practical considerations in search and rescue, triage, treatment and animals' final destination.

Scene recognition, for example, is very important when planning fauna protection. It involves analyzing fire characteristics and environmental conditions alongside wildlife occurrence records. After initial assessment, monitoring can then include the identification of the direct effects of fire on fauna through estimating the impact on animals, alive or dead, in various locations (DELWP 2018).

Search and rescue are the main objectives of response actions, to capture those animals directly affected by fire that have suffered burns or severe dehydration. Removing animals from areas at imminent risk of burning, through preventive capture and other evacuation strategies, is not simple, however, and may not be practicable due to the safety considerations for fire crews. One successful example, was the evacuation of 20 endemic birds (Eastern bristlebird/*Dasyornis brachypterus*) during the 2019–20 wildfires in Australia, eight of which were later returned to the wild (Parrot et al. 2021). All individuals with obvious burns and respiratory damage should be removed, but not all animals need to be rescued. Deciding which animals to rescue should be based on an assessment of behaviour, mobility, body posture, dehydration, external damage, respiratory impacts, and other clinical signs.

Triage is also needed. This means that the priority of care is decided depending on the severity of health conditions, potential response to treatment and post-rehabilitation return to the wild, and the species' conservation status. During triage, euthanasia must also be considered in cases when burns cover more than 20% of an animal's body or affect critical regions such as the genitals and cornea, if continuous and prolonged treatment would be required, if severe dehydration suggests renal failure, if there is a loss of metabolic, respiratory and cardiovascular capacities, or if there are comorbidities, infectious diseases or fractures.

Rehabilitation includes the treatment of injuries, the reconditioning of animals that have a favourable prognosis, their return to the wild, and monitoring afterward. Rehabilitation also allows additional assessments to be made to identify pathogens associated with rescued species. This is part of a broader effort to monitor emerging zoonotic diseases in order to carry out preventive surveillance of infectious agents in wild animal populations.

Mitigation actions

In order to reduce fire intensity and the size of the area burned, integrated fire management is a mitigation measure that can also decrease animal mortality. In addition it can lead to the development of landscape mosaics that provide refuges for animals and minimize their displacement. Environmental fragmentation can contribute to population isolation and decline over the long term, reducing animals' ability to survive by taking shelter in adjacent areas. In landscapes that are increasingly fragmented, animals are forced to search for resources in more distant areas, and may therefore carry pathogens to new areas where they did not previously occur and so could affect new hosts, including humans. Animals are also vulnerable to the impacts of hunting and trampling.

In Brazil, there are successful examples of prescribed burning carried out by traditional communities (Xerente and Oliveira 2021), and by managers in the country's conservation units (Schmidt et al. 2018; Barradas and Ribeiro 2021). These aim to reduce the availability of combustible material, and it is expected that such activities will be regulated in the future as public policy. However, few studies recognize the effects of fire management on wildlife. One study, carried out in native grasslands in the Araucaria Plateau in southern Brazil, identified higher avifauna richness and abundance in the fire treatment area after burning (Petry et al. 2011). Prescribed fire initiatives could include more actions that reduce or minimize risks to the health of wildlife, and that could be carried out in plot sizes that correspond to the mobility of local fauna to move away from and through burned areas. Additionally, the timing of controlled burns must not correspond to peak reproduction periods.

Prevention

Brazil has instruments and regulations on responsible fire management and fire suppression, e.g., Decree 97.635/1989, Law 9605/98, Decree 2661/98, Decree 6514/2008 and Law 12651/2012. Supported by good governance, these can break the cycle of wildfires as disaster events, alongside effective enforcement that either prohibits the use of fire or promotes controlled burns. The controlled use of fire reduces damage to and losses of native wildlife, and is supplemented by government policies for wild animal protection; e.g., Law 5197/67 and Law 9605/98.

In 2021, the National Wildlife Rescue Program was initiated by Brazil's Ministry of the Environment, within the legal framework for reducing the impacts of wildfires on wildlife. Its main objectives are to provide legal tools for animal rescue, emergency veterinary medical care, and assistance to vulnerable wild fauna in risk situations. Objectives also include mitigating the loss of biodiversity resulting from extreme natural events or from environmental accidents caused by human actions. It is being implemented in the Pantanal region, mainly in Mato Grosso do Sul State; a veterinarian field hospital was established there in October 2021, under the command of the firefighters. In this initiative, wildlife responders are integrated in the Incident Command System that is part of Fire Response Operations. This organizational structure aims to support the rapid and effective rescue, transportation and rehoming of wildlife to improve survival rates.

Building resilience

Wildlife management must be integrated into wildfire protection and management policies. It must include multisectoral and interdisciplinary coordination that plans and implements strategies to minimize risks and vulnerabilities, and to maximize the quality of care for affected animals. At the same time, it is necessary to establish regional and international policies and cooperation, since ecosystems, wildlife, pathogens and wildfires recognize no borders. Since the health of animals, humans and ecosystems is intimately integrated and interdependent, sustainable wildlife management in wildfires can also improve outcomes for biodiversity conservation and contribute to One Health resilience.

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Section 3

Asia

Photo, previous page: Forest fire fighting using hand tools. Photo: Pak Doni

Peatland fire burning in the Pawan-Kepulu-Pesaguan landscape, Ketapang District, Indonesia. Photo: Irpan Lamago

3.1

Integrated landscape approaches for reducing peatland fires in Ketapang District, Indonesia

Atiek Widayati, Lisa Tanika, Kasuma Wijaya, Ali Yansyah Abdurrahim, Edi Purwanto, and Roderick Zagt

"Multistakeholder participation and the use of inclusive processes, especially in water management and promoting peatland-adaptive practices, are seen as key to reducing fires in peatlands."

Introduction

During years with frequent fires in Indonesia, such as 2015 and 2019, Ketapang District in southwestern West Kalimantan Province received national and international attention. West Kalimantan has about 1.7 million ha of peatlands, the fourth largest in Indonesia, and 253,000 ha of which are in Ketapang District. Most have been cleared or heavily degraded. Global Forest Watch reported that between May 2019 and May 2020, Ketapang had the highest number of active fires in the province. Most were in peatland areas; some were in upstream areas where traditional shifting cultivation is still practised.

This article presents initial findings and lessons learned from Tropenbos Indonesia's implementation of the Fire-smart landscape governance programme. The project area is the Pawan-Kepulu-Pesaguan landscape in Matan Hilir Selatan sub-district of Ketapang, which covers almost 80,000

ha (Figure 1). The landscape consists of two peatland hydrological units (PHUs): Pawan-Kepulu (64,000 ha) and Kepulu-Pesaguan (13,000 ha). These have approximately 50,000 ha of peatlands in their core areas; their peripheries, close to rivers, have non-peat (mineral) soils. The area has 20 villages, including those outside of the peatland ecosystems; e.g., along rivers and in coastal areas. Of these, five to six villages are in peatlands that have been affected by fires.

Peatland fires in the Pawan-Kepulu-Pesaguan landscape

Large fires have been burning in the landscape since 1997, a year when the El Niño-Southern Oscillation caused severe and extended droughts. Some fires were started intentionally in degraded areas, where canals have been built to drain peat for agricultural development and to transport logs from the forest. Land clearance by burning is common when native forests and peatland vegetation is converted to oil palm plantations and agricultural land. Oil palm development in this landscape began in the early 2000s with large-scale plantations, followed by independent smallholders.

Deep-peat 'peat domes' (>3m depth) cover 27,000 ha in Pawan Kepulu PHU (KLHK, 2015), but canal were also constructed in these areas, that should be protected by law. The deepest peat found from a survey by Tropenbos Indonesia was 9.8 m. It is dominated by fibric (slightly decomposed) peat and hemic (moderately decomposed) peat, which indicate high water retention capacity. However, when canals are built, this capacity is disturbed, resulting in highly flammable dry peat (Paul et al. 2018).

After large areas of the landscape were converted to oil palm, fire frequency and severity increased. Since 2013, fires have been set every year during the dry months of August and September, especially in 2015 and 2019. Peatland fires create prolonged small flames with thick and persistent smoke, causing extreme pollution, low visibility and haze. Peatland fires in Ketapang drew concerns at district, provincial and national levels as their impacts were widespread, severely affecting human health and air traffic at the nearby international airport in Pontianak, and with negative impacts on agricultural crops and ecosystems.

Most of the landscape (70%), including most deep peat areas, is classified as non-forest land (i.e., land allocated for other uses, also called private land). The remaining 30% is forest land, classified as production forest or convertible production forest. Peat swamp forests are found in production forest areas managed by three villages: Pematang Gadung, Sungai Besar and Sungai Pelang. In the early 2000s, secondary peat swamp forests covered 26,000 ha, but this had declined to only 9,000 ha by 2019.

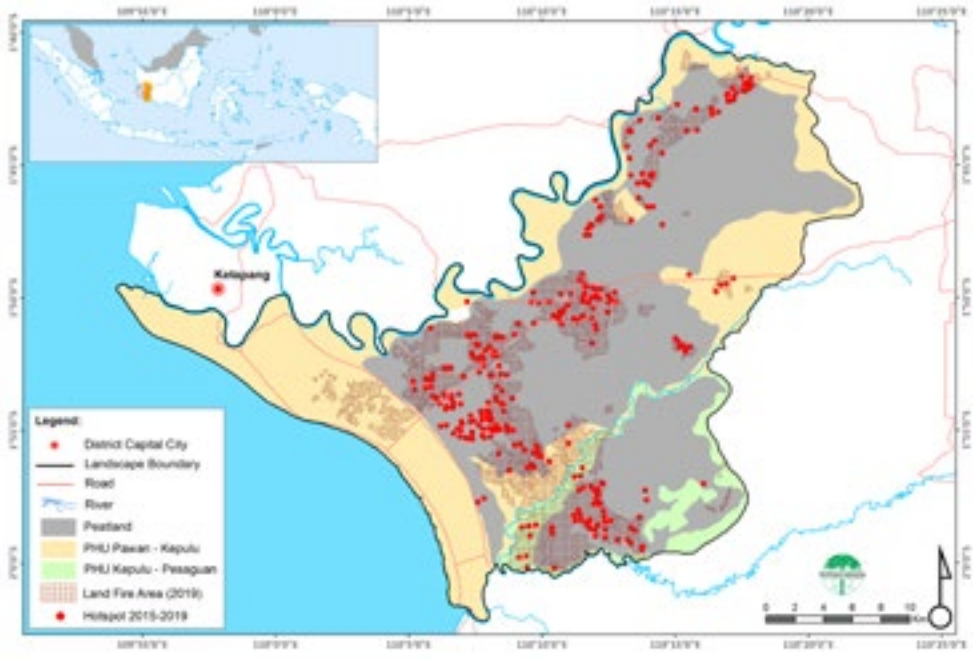

Figure 1. The Pawan-Kepulu-Pesaguan landscape in Ketapang district, West Kalimantan Province, Indonesia, with locations of satellite-detected active fires between 2015 and 2019

Burned forest in peatlands in Pawan-Kepulu-Pesaguan, Ketapang District, Indonesia. Photo: Irpan Lamago

Policy responses at national and sub-national levels

In response to the large fires of 2015, the Indonesian government developed policies and regulations. Peatland restoration was high on the agenda, marked by the establishment of the Peatland Restoration Agency by a Presidential decree in 2016. That same year, the Ministry of Environment and Forestry enacted a Forest and Land Fire Prevention and Suppression regulation to be applied at district, provincial and national levels.

Following the establishment of the agency, between 2016 and 2021, the national government enacted numerous regulatory instruments and technical guidelines on peatland ecosystem protection, management of peat domes, and restoration of peatland ecosystems, among other matters. It also issued regulations to address land and forest fires. A key regulation enacted by the Ministry of Environment and Forestry in 2021 emphasized integrating fire prevention and mitigation in disaster management action plans.

West Kalimantan and Ketapang governments responded with provincial and district regulations and other instruments. As mandated by the national regulation, Ketapang District established the Forest, Plantation and Land Fire Prevention and Suppression Taskforce. This coordinating hub involves government offices and non-government actors and is led by the district head. The district reinforced fire prevention regulations through campaigns and appeals to local communities and other actors not to start fires. The district government also articulated the need to protect deep peat areas in its spatial planning document issued in 2015.

Addressing fires in production landscapes

Landscape approaches

Indonesia's peatlands are largely designated for productive allocation and use. However, with increasing risks of land-use fires getting out of control and resulting in wildfire disasters, in addition to greenhouse gas emissions, biodiversity loss and other environmental issues, it is necessary to address multiple objectives in their management. In response, landscape approaches have brought concepts and tools to achieve diverse social, economic and environmental goals; this requires reconciliation between multiple stakeholders in landscape governance (Zagt and Chavez-Tafur 2014).

Implementing landscape management approaches requires a set of principles. Sayer et al. (2013) proposed ten elements: continual learning and adaptive management, common entry point, multiple scales, multifunctionality, multiple stakeholders, negotiated and transparent changes, clear rights and responsibilities, participatory monitoring, resilience, and strengthened stakeholder capacity. Similarly, Scherr et al. (2013) emphasized that integrated landscape management must include shared or agreed management for multiple objectives; practices that provide multiple benefits; interactions of landscape actors that maximize synergies; collaborative, community-based processes; and supporting policies and markets.

Remaining forests, drainage canal and degraded peatland in Pawan-Kepulu-Pesaguan, Indonesia. Photo: Irpan Lamago

Fires-smart territories

The fire-smart territory (FST) approach integrates economic and social activities. It aims to reduce risk and conserve natural values and ecosystem services by empowered communities who are able to determine objectives and practices for the prevention, control and use of fire (Tedim et al. 2016). Adapting this approach to Indonesian peatlands must focus on the adoption and practice of collaborative governance and adaptive management. Tedim et al. (2016) listed eight principles of the FST approach: heterogeneity, adaptability and flexibility, cooperation, complementarity, empowerment, attenuation, scaling, and modularity.

Addressing peatland flammability

Addressing fire risk in highly degraded peatlands must reduce flammability. To achieve this, Indonesia's Peatland and Mangrove Restoration Agency (the successor to the Peatland Restoration Agency since 2021) developed the "three Rs" strategy: rewetting, revegetation and revitalization. Rewetting is the key stage and is usually undertaken through the construction of canal blocks. This is followed by revegetation. Revitalization strengthens economic development and livelihoods and supports the sustainability of the restored peatlands.

Agricultural production on peatlands is sometimes a priority, as in the Pawan-Kepulu-Pesaguan landscape. Combining productive and protective functions can be achieved through adaptive practices, either as a long-term goal or as an intermediate phase prior to full restoration (Widayati et al. 2016); see Figure 2. Where rewetting cannot be optimally carried out, managing peatlands for productive purposes must focus on minimal drainage, crops that tolerate high soil moisture (paludiculture), no tillage, and planting dense tree crops to reduce surface temperatures (Joosten et al. 2012).

The three R's strategy and support for production-protection functions must both consider landscape variations and complexities. In some areas, it may be feasible to fully restore peatlands; in others, it might be only partly feasible; e.g., by improving agricultural productivity through various measures, no-burn policies and water-level patrols.

Gaps and barriers

In Pawan-Kepulu-Pesaguan, unsuitable land designation and land-use planning are long established, including the building of transmigration settlements and a major provincial road network by governments. In addition, deep-peat areas are designated as private land and are not protected. This allows them to be converted for oil palm and agriculture, which leads to frequent fires during long dry seasons.

The national government faces a dilemma: support economic development or shift to protection measures that compromise such development, with few initiatives that address the factors that underlie the need for protection. Despite the mandate to protect deep-peat areas in district spatial planning, operational action plans were not developed and most resources are allocated to fire suppression and disaster management. In addition,

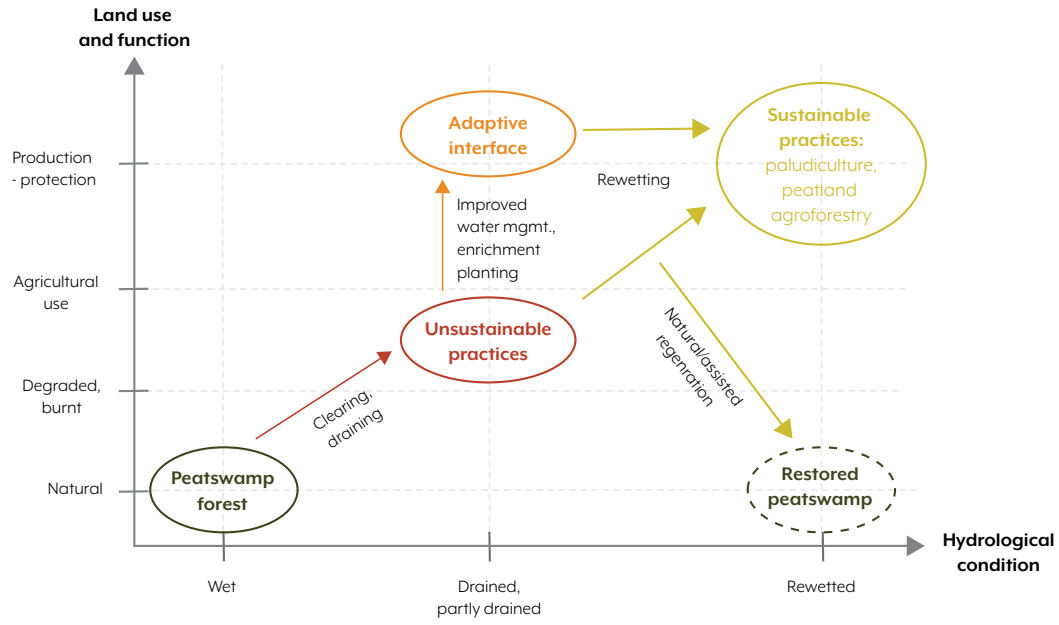

Figure 2. Options for promoting productive-protection peatland functions (adapted from Widayati et al. 2016)

the effectiveness of efforts is reduced due to overlapping land claims and tensions over land rights. Lack of capacity and lack of knowledge on the part of communities and local government are other significant barriers.

Burning continues to be perceived as the cheapest way to clear land and improve soil fertility. In addition, the common preference of oil palm companies and smallholders is to keep water tables low using drainage canals, and they tend to be reticent to consider an increase in water levels. There is also a well established market for palm oil, making it difficult for smallholders to find equally profitable alternative, let alone any that are based on the productive use of wet and rewetted peatlands (Wichtmann et al. 2016).

Multiple approaches

To address peatland fires and the interconnected issues in Pawan-Kepulu-Pesaguan, the project aims to improve governance and management of the landscape in order to support adaptive practices and sustainable use. A variety of approaches were explored to achieve collaborative efforts by diverse stakeholders under an integrated landscape approach. A jurisdictional approach was incorporated, especially at the district level, by developing planning, regulatory instruments and implementation tools. Partnership with the private sector by means of responsible financing schemes was also explored.

The means to implementing multiple approaches include: (i) improving understanding through diagnostic steps and knowledge development; (ii) developing a theory of change for target actors; and (iii) developing integrated and scalable intervention strategies at various levels (Figure 3). The pathways work as a feedback loop and involve iterative processes throughout.

Through a theory of change, Tropenbos Indonesia envisioned that processes, actions and targeted changes are carried out by the target actors: governments in relevant sectors, private actors (mostly in the oil palm sector), smallholders and communities. The programme established multistakeholder working groups at district and sub-district landscape levels to identify common issues and build shared visions through consultation and negotiation. Landscape-level outcomes and outputs were targeted for collaborative efforts with external stakeholders (Figure 3):

- **Planning and regulatory instruments at landscape and village levels** were developed to implement enabling conditions at the village level, such as village regulations (*Peraturan Desa-PerDes*) and inclusion in village development planning.
- **Landscape and village institutions** were strengthened through multistakeholder working groups at the sub-district level, followed by the strengthening of village governments and other local institutions such as village forest management units (*Lembaga Pengelola Hutan Desa*), business units in villages (*Badan Usaha Milik Desa*) and village forests (*Kelompok Usaha Perhutanan Sosial*).

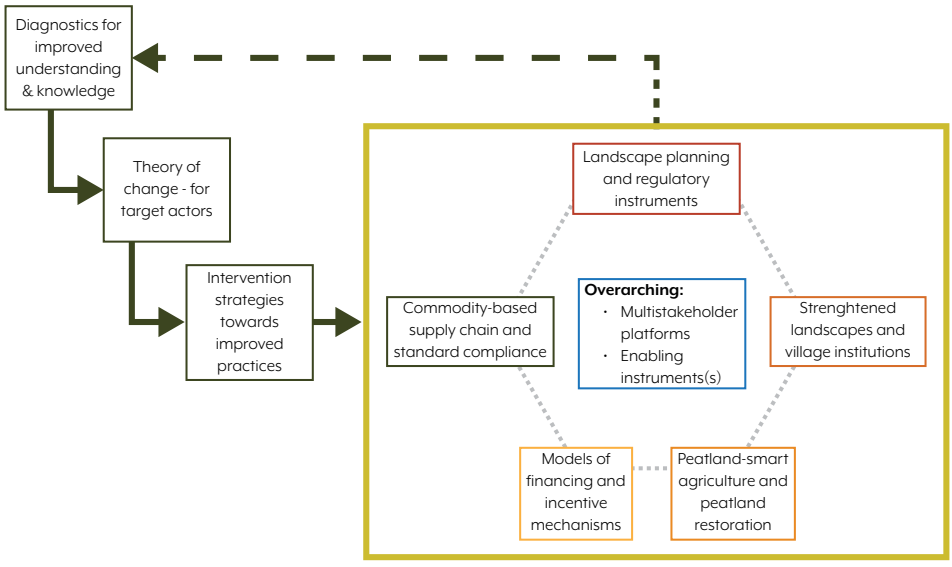

Figure 3. Pathways in implementing multiple approaches for fire-smart peatland landscapes

- **Peatland-smart agriculture and peatland restoration** were supported through capacity strengthening for peatland-adapted good practices, establishing demonstration plots, exploring alternative livelihoods, and support for restoring degraded forest areas.
- **Models of financing** were explored and developed for forest protection, fire prevention and peatland-smart practices through responsible financing schemes, jurisdictional, ecological-based fiscal transfers and village funds.
- **Commodity-based supply chains and standards** were connected to oil palm best practices for independent smallholders and large-scale palm oil producers.

Landscape-fire typology and prioritization

Pawan-Kepulu-Pesaguan can be categorized according to five site types, from satellite-detected fire data (2015-2019), historical fire locations, peatland and hydrological characteristics, land status, actors involved, and land use/cover (see Table 1 and Figure 4). Based on the five landscape types and on targeted improvements, developing these landscape planning instruments should be a priority (Table 2).

Table 1. Site type, Pawan-Kepulu-Pesaguan, based on dominant characteristics

Type	Fire-prone areas	Peatland	Land status/actors	Land cover	Location
1	Fire areas are large and many	Dominant deep-peat areas (>3m), extensive canals	Private land, community and oil palm concessions, overlapping claims	Shrubs, cleared areas with young oil palm, oil palm plantations	Large parts of Sungai Pelang and Sungai Besar, oil palm concessions
2	Fire areas are large and many	Varied peat depths, fewer canals	State forest, production forest (community managed and village forests)	Shrubs and dry agriculture	Pematang Gadung village
3	Fire areas are smaller and fewer	Shallow peat and mineral soils, no canals	Private land, with unclear tenure	Shrubland and cleared land	Pawan River, bordering oil palm concessions
4	Fire areas are small and very few	Varied peat depths, few canals	Village forest schemes in production forests	Secondary peat swamp forests	Village forests of Sungai Besar and Pematang Gadung
5	Minor fire areas	Varied peat depths, many canals	Private land, oil palm concessions	Oil palm plantations	Oil palm concessions

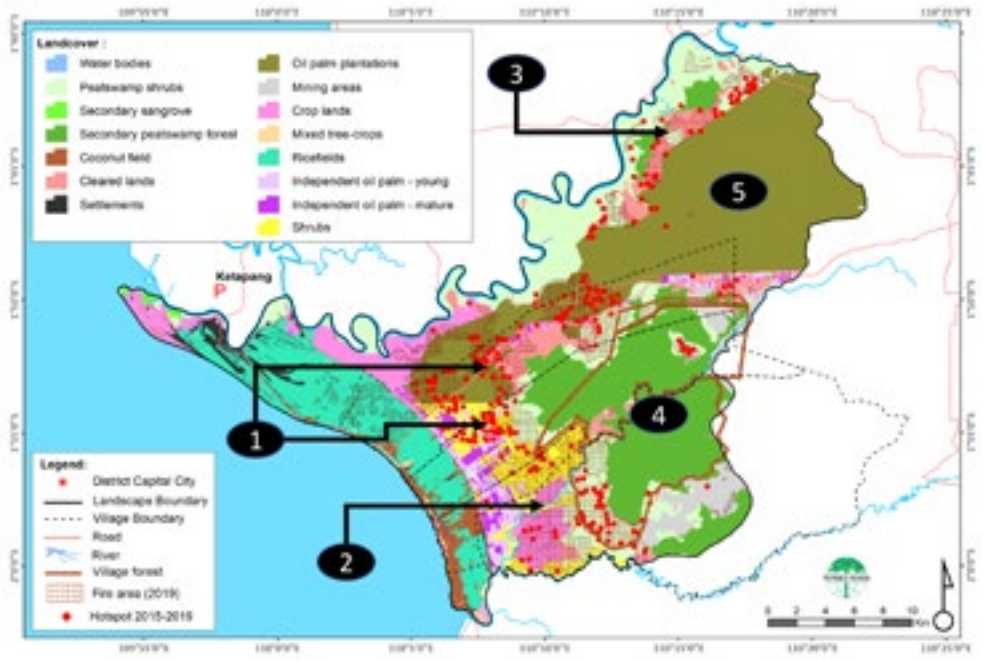

Figure 4. Divisions in Pawan-Kepulu-Pesaguan based on fire locations, peatland characteristics, land status and land use/ cover (for description of numbered site types see Table 1)

Table 2. Proposed prioritization of activities for different peatland site types

Type no.	Characteristics	Priority
Type 1	Peat dome areas with frequent fires, and no restriction in land use	Peatland protection zoning, to be regulated at the district level. Considerations of whether to allow agricultural practices or production functions must be based on sustainable -peatland management.
Types 2 and 3	Various fire-affected areas and sites of varying peat depths	Integrated fire prevention and management that acknowledges complexities in land status, land use and actors involved, also aiming to incorporate productive agricultural practices and peatland protection functions.
Type 4	Areas with minor fires, varied peat depths, few canals, dominated by remaining peat swamp forests, with illegal mining as an imminent threat in neighbouring areas	Forest protection and restoration, and sustainable wet peatland practices. These should be supported by financing schemes to ensure protection, revegetation of degraded forests and provision of alternative livelihoods.
Type 5	Areas dominated by large-scale oil palm plantation with many canals, but only minor fires detected	Good agricultural practices, promoted in partnership with smallholder cooperatives, and with upscaling through sustainable oil palm supply chains.

Lessons learned

Various approaches to achieve a fire-smart landscape through peatland-adaptive practices have been explored in Pawan-Kepulu-Pesaguan at the district, landscape and village levels. Multistakeholder participation and inclusive processes are key, where trust has been built and collaborative actions are pursued across multiple scales. National to sub-national linkages have been made through the involvement of the Peatland and Mangrove Restoration Agency. Capacity strengthening for good agricultural practices has included training of local champions to play important roles in sustaining and spreading their use. Financing has been introduced through a responsible financing scheme managed by organizations such as Lestari Capital. Other financial mechanisms, such as jurisdictional, ecologically based fiscal transfers require further investigation.

Work to date in Pawan-Kepulu-Pesaguan has shown the importance of collaboration and cooperation, and of empowering communities and local actors, and understanding the complementarity of their respective roles and responsibilities. Programme activities are ongoing, but have already demonstrated that a holistic approach is necessary due to the competing and conflicting interests that underlie fires in this production landscape. Land and tenure rights are also a major issue and one of the most intricate to resolve. Promoting multifunctionality and resilience through diverse agroforestry systems on restored peatlands remains challenging where monoculture oil palm dominates, and such landscape transformation requires enabling policies and supportive markets.

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Fighting fires in Viet Nam. Photo: Department of Forest Protection

3.2

The decreasing trend of forest fires in Viet Nam and lessons learned

Nguyen Thi Thuy, Hoang Viet Anh, and Tran Lam Dong

"As a result of effective policies, Viet Nam has reversed the trend that has seen increases in the frequency and intensity of forest fires around the world."

Introduction

A wide range of climates and a complex topography shape Viet Nam and its diverse forest ecosystems. These include tropical forests, deciduous dipterocarp forests, pine forests, peat swamp forests, degraded forests and plantations. Forests today cover 42% of the country, but this was not always the case. Forest cover fell from 43% in 1945 to 27% in 1990 (de Jong et al. 2006), when the remaining natural forests were so significantly degraded that many state forest enterprises had no more timber to harvest (Phúc and Nghi 2014).

Before 1975, during the years of civil war, forests were overexploited for timber that was exported as a source of revenue (Phúc and Nghi 2014), and many forest fires were caused by aerial bombardment and intentional burning (Chandler and Bentley 1970). Migration to mountainous areas was common until the 1990s (Marx and Fleischer 2010), when fire was often used

More than four million hectares of plantations have been established in Viet Nam, commonly using exotic acacia species. Photo: Tran Lam Dong

to clear land for agriculture and in shifting cultivation (Westing 1983; Truyên 2007). Such practices remained widespread among many ethnic minorities in the Central Highlands and the northwest until the 2000s (Hai et al. 2009; Quê et al. 2009).

Although wildfires have been a recurring problem, the total number of fires and the annual of burned areas have both been declining in the past two decades. This article outlines the government policies and other factors and their respective roles in explaining the decrease in forest fires and the lessons learned from forest fire prevention and firefighting in Viet Nam. To put these policies into local contexts regarding fire trends, capacities and gaps, a survey of 28 staff members involved in fire prevention and firefighting from 28 organizations was undertaken. The survey information is reported for the first time in this article.

National trends in forest expansion and fire reduction

In 1990, the national government responded to the alarming trend of forest degradation. By 2020, after 30 years forest cover had increased to 42%. This comprised 10,279,185 hectares (ha) of natural forests and 4,398,030 ha of plantations (Decision No. 1558/QĐ-BNN-TCLN); most of the expansion is due to the doubling of the area of plantations (Figure 1).

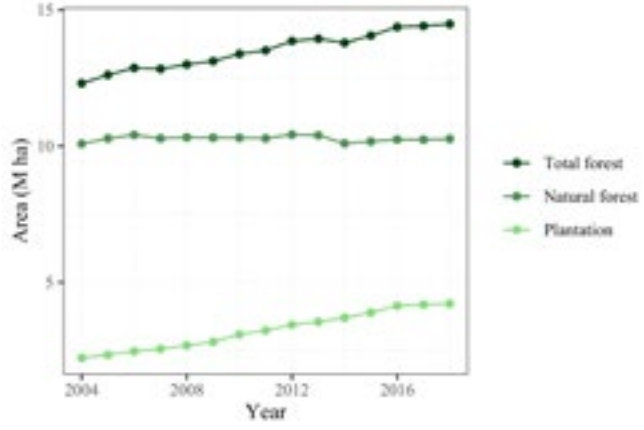

Figure 1: Forest area in Viet Nam (2004–18). Source: Ministry of Agriculture and Rural Development (MARD).

The 1991 *Forest Resources Protection and Development Act* divided forests into three types — special-use, protection and production forests — and required the management and protection of each type to comply with specific regulations. This classification supports effective forest management while also ensuring forest conservation and economic development:

1. Special-use forests are managed mainly for the conservation of nature, biodiversity and genetic resources, for the preservation of historical and cultural relics, and for scientific research.
2. Protection forests protect water sources, reduce soil erosion, reduce desertification, reduce impacts

from natural disasters, and help to regulate the climate, etc.

3. Production forests aim at the production of timber and non-timber forest products, and their subsequent processing and trade.

Since 2004, an average of 3,803 ha of forests have burned each year: 1,025 ha of natural forests, and 2,777 ha of plantations. The annual number of fires and size of burned areas have fluctuated considerably, but both show an overall decreasing trend (Figure 2a and 2b). Disaggregated data for the period between 2005 and 2010 (Figure 2c and 2d) confirm that fires are much more common in plantations than in natural forests. The forest fire season is December to May in most ecological regions, and from March to September in the north central and south central coast regions (MARD 2007).

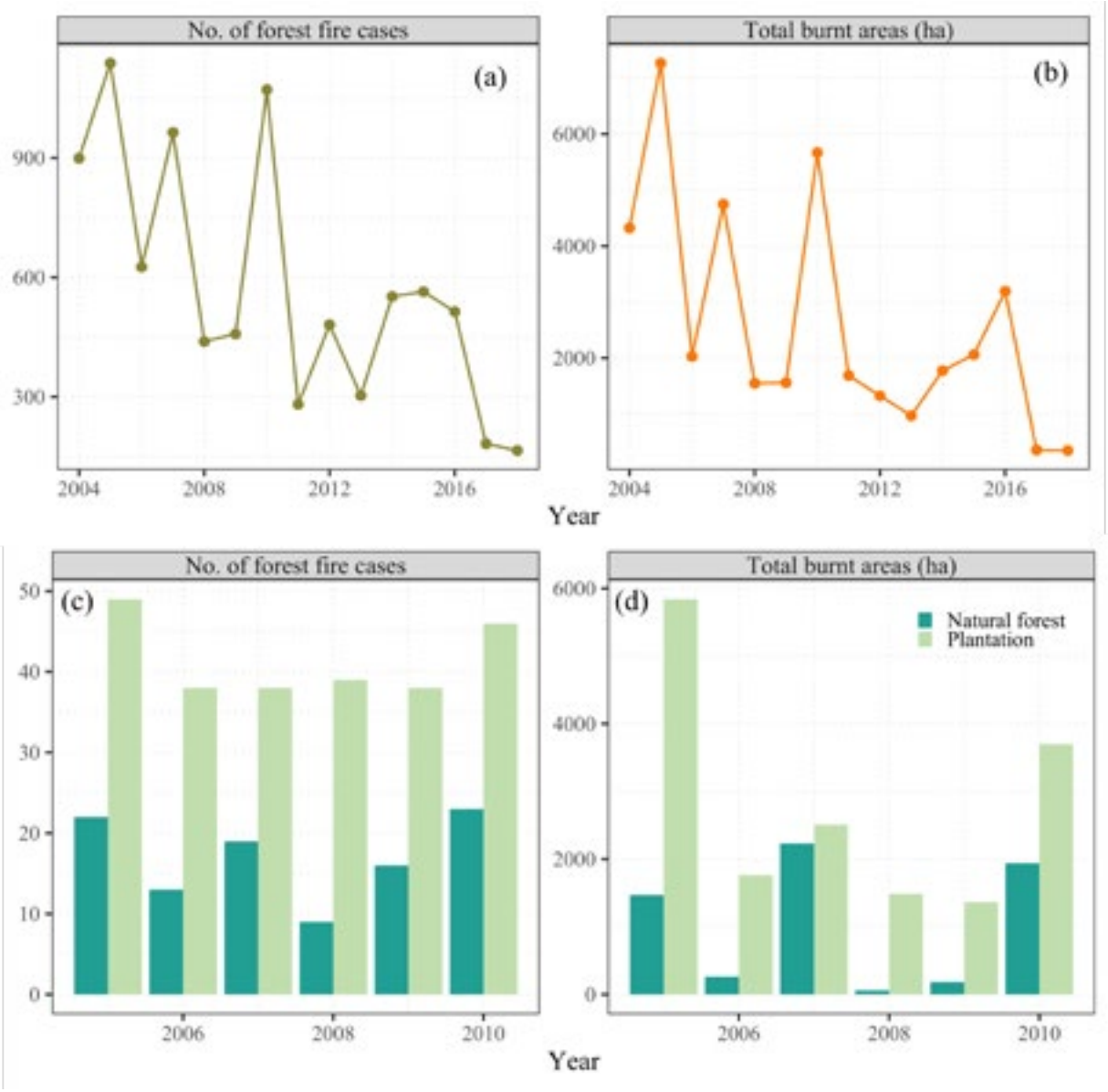

Figure 2: The number of fires and area burned annually, as national totals between 2004 and 2018 (a and b), and between natural forests and plantations between 2004 and 2010 (c and d). Source: Viet Nam Forest Protection Department

Degraded tropical forests are especially vulnerable to fire in the dry season. Photo: Ninh Viet Khuong

The role of government policies since 1990

Recognizing and responding to forest degradation, the national government issued nearly 150 policies related to forest protection and development between 1990 and 2001 (Sam and Trung 2003). The most important ones were the *Law on Forest Protection and Development* in 1991 (No. 58-LCT/HĐNN8), and the 1993 *Law on Land* (No. 24-L/CTN), which supported land allocation to various entities in the subsequent two decades. In 1998, the government began a programme to reforest five million hectares (No. 661/QĐ-TTg) which built the foundation for the development of plantations in Viet Nam.

Other policies in the 1990s and 2000s were issued to support the resettlement and economic development of poor ethnic minority people (e.g., Decrees No. 135/1998/QĐ-TTg, No. 134/2004/QĐ-TTg, and No. 33/2007/QĐ-TTg). These policies improved livelihoods and markedly reduced negative impacts on forests, including forest fires (Tinh and Nghi 2012).

The 1991 *Forest Resources Protection and Development Act* prohibited burning on forested land, and specified that state agencies were responsible for formulating and directing the implementation of plans for forest fire prevention and firefighting. Responsibility later shifted to all forest owners, including individuals and local communities, following the 2004 *Forest Protection and Development Law* (Decree No. 29/2004/QH11); this was further refined in 2006 through Decree No. 09/2006/NĐ-CP and through the 2017 *Law on Forestry* (Decree No. 16/2017/QH14). These laws also specified the forest protection responsibilities of ministries and ministerial-level agencies. Sanctions for violence in forest protection and forest fires have been specified in the Criminal Code (Decree No. 15/1999/QH10) since 1999.

The 2004 *Forest Protection and Development Law* was particularly important in defining the role of forest ranger forces (which were first established in 1973 under Decree No. 101-CP). These specialized units are responsible for developing forest fire prevention and firefighting programmes and plans, forecasting and early warning, and training forest owners in developing and implementing plans for forest fire prevention and firefighting. The 2004 law also provided the legal basis for payment for forest environmental services (Thuy et al. 2013), which has significantly contributed to forest protection and fire prevention. By 2020, payments were received for 6.7 million ha of forests (VNFF 2021).

The *Law on Forestry* in 2017 (further clarified in Decree No. 156/2018/NĐ-CP) regulated the use of fire in and near forests, as well as fire prevention and firefighting, stipulating responsibilities for developing fire prevention and firefighting plans. The law also regulated the valuation of compensation when forest fire occur, and the forest fire prevention and firefigting policies related to investments in resources, equipment, monitoring and early warning systems. Circular No. 25/2019/TT-BNNPTNT also specified the need for training in forest fire prevention and firefighting. See Figure 3.

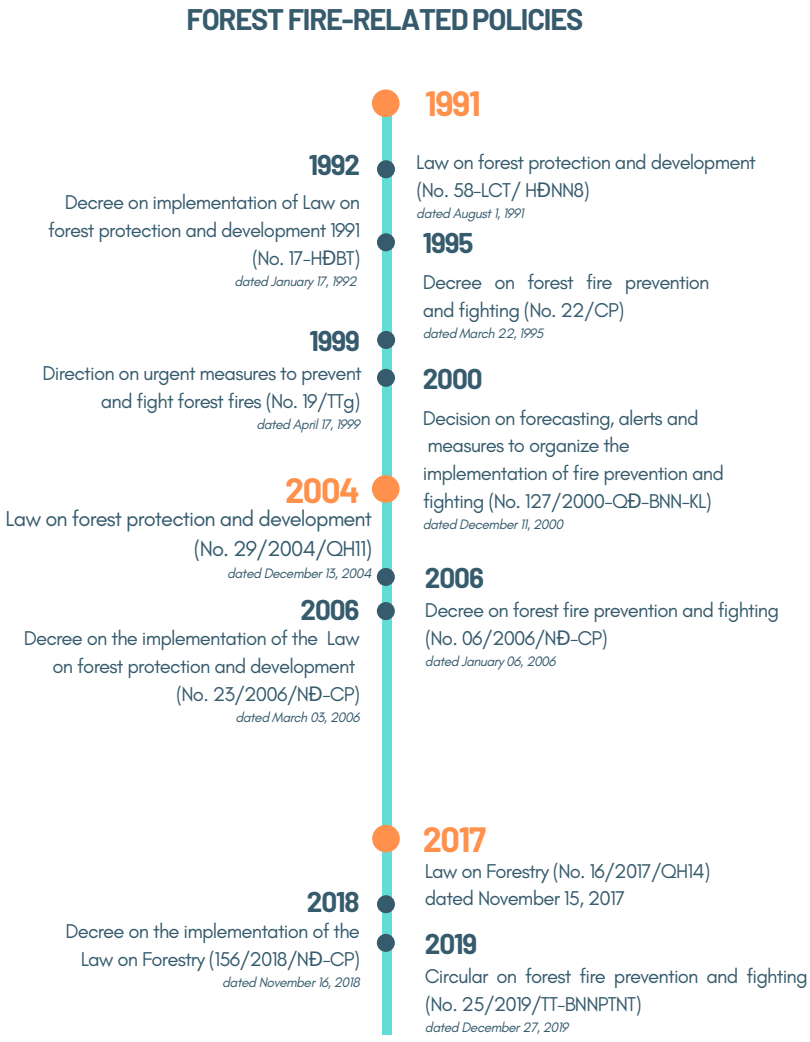

Figure 3: Major policies in Viet Nam related to forest fires, 1991–2019

The national government has also promoted sustainable forest management and livelihood development initiatives for local people. The country is a signatory to international treaties such as the United Nations Framework Convention on Climate Change (MoNRE 2020), and also introduced REDD+ to Viet Nam. This helped to raise awareness of the need to protect forests, reduce deforestation and prevent forest fires. In addition, sustainable forest management and forest certification schemes, in which there is no burning, have been applied on more than 300,000 ha (Vietnam Administration of Forestry 2021), mainly in plantations.

Forest fire prevention and firefighting

In order to understand local perceptions of forest fires, an online survey of 28 staff members was undertaken in January 2022, mostly technical experts, from 28 forest management organizations across Viet Nam. The questionnaires were developed by the authors and shared publicly. They were designed to collect information on six topics:

1. forest fire prevention and firefighting experiences;
2. technologies and tools used;
3. capacities and training;
4. experiences of the organization in preventing and fighting forest fires;
5. understanding of related regulations and policies; and
6. the forest management resources of the organization.

The participating organizations were from the Northwest (Hoa Binh, Lai Chau, Son La), Northeast (Ha Giang, Phu Tho, Lao Cai, Thai Nguyen), North Central Region (Thanh Hoa, Nghe An, Thua Thien Hue, Quang Tri), South Central Coast (Quang Nam, Quang Ngai, Binh Dinh, Ninh Thuan,

Burning residues after harvesting in plantations. Photo: Tran Lam Dong

Binh Thuan), Central Highlands (Dak Nong, Lam Dong), and Southeast (Ba Ria – Vung Tau). They included sub-departments of forest protection bodies, management boards of protected areas, and forest rangers at the commune level.

Nearly 60% of the survey respondents reported forest fires in their jurisdictions every year; 36% said that burning occurred every few years. However, the majority of respondents (85%) believed that the frequency of forest fires had been decreasing or had not changed in the previous 10 years (Figure 4). They largely saw this trend as the result of new policies that have led to increased local awareness of the risks of fire and to improved forest management. Only three respondents (10%) stated that forest fires had increased, due to climate change, the spread of unintentionalfires, and conflicts. Most burned forests occur in acacia and pine plantations, and in natural deciduous dipterocarp forests, regenerated and degraded forests, and grasslands.

Most forest fires in Viet Nam are caused by human activities, both intentional or unintentional. The three most important causes indicated by survey respondents were 1) slash-and-burn (shifting) cultivation and 2) illegal hunting (including honey collection), which usually occur in natural forests, and 3) activities related to plantations (Figure 5), where burning residues after harvesting is the main cause of forest fires. In addition, participants regarded conflict as an important cause of forest fires, particularly in plantations. Unintentional burning was

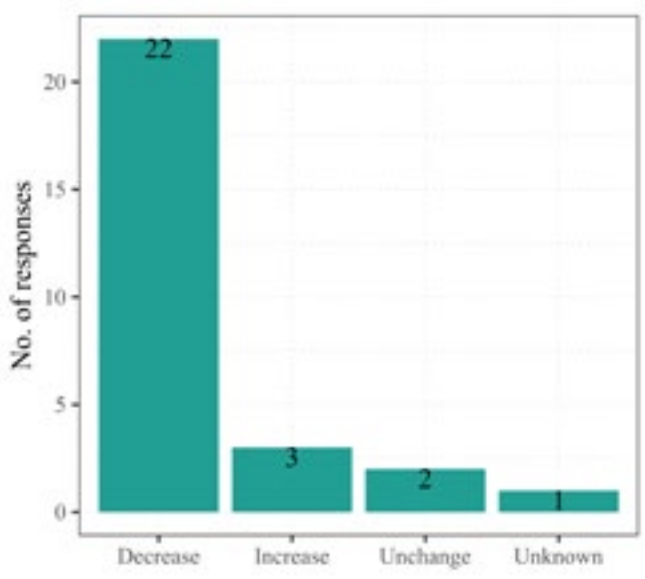

Figure 4: Perceived trends in the occurrence of forest fires between 2010 and 2020

indicated as a most important cause more often than illegal logging, prescribed burning and other causes were. Prescribed burning is most common in deciduous dipterocarp forests.

In addition to the use of watchtowers, walkie-talkies and basic firefighting tools, three-quarters of respondents reported that their organization uses the Forest Protection Department's online forest fire-monitoring system and SMS message notifications for the early detection of fires. Remote sensing and GIS, however, were used by only 7

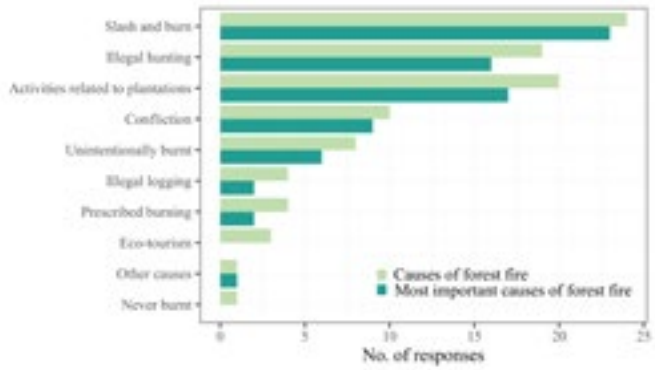

Figure 5: Causes of forest fires according to survey respondents

of the 28 organizations (25%), and other technologies were rarely used. One-quarter of the organizations use no advanced technology in forest fire prevention and firefighting. Almost two-thirds of the organizations (64%) had fewer than five staff members with skills in mapping, GIS, remote sensing and other technologies related to forest fire prevention and firefighting. However, in response to this situation, one-quarter of organizations were running two to five training courses per year on forest fire prevention and firefighting, and more than half ran at least one course per year. Training is carried out to improve the capacities of technical staff, local people and local authorities in measures that prevent forest fires, activities that can cause forest fires, determining potential locations of fires, the use of equipment, building firebreaks and firefighting demonstrations (Figure 6).

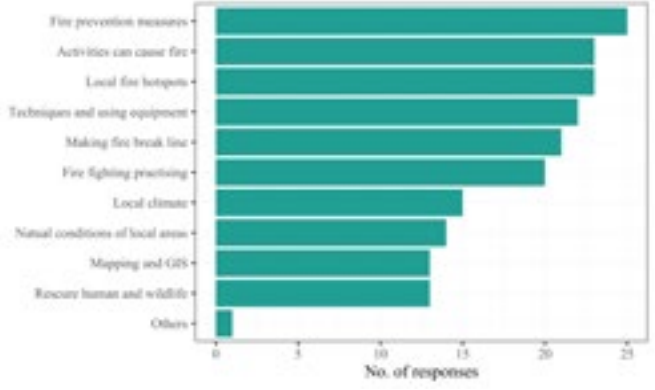

Figure 6: Training topics, forest fire prevention and firefighting

Given the limited resources for and capacity in forest fire prevention and firefighting, the dissemination of information in local areas is critical. Survey respondents indicated that the most effective means of providing information were local meetings, loudspeakers in the communities, noticeboards that rate forest fire danger, leaflets, individual reminders, social media, and television (Figure 7).

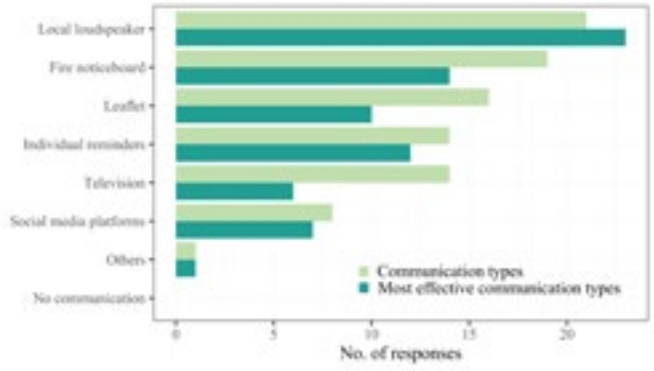

Figure 7: Communication on forest fire prevention and firefighting

Conclusions

Over the past 15 years, forest fires in Viet Nam have been decreasing, with fires now occurring more often in plantations than in natural forests. The most important drivers of this decreasing trend have been the enactment and effective implementation of policies that support forest and land allocation and economic development, together with strict regulations on forest protection. In terms of policy, Viet Nam appears to be a model that other countries could follow.

Given the fire-related issues associated with plantations, the increase of plantation areas, especially in the context of climate change, can be a challenge for forest management. With only modest numbers of staff members working on fire preventing and firefighting, and with limited equipment and resources, it is very important to raise awareness, improve technical capacities and disseminate information on forest fire prevention and firefighting for both local officials and forest owners. The results of the survey reported in this article indicate gaps that still need to be filled.

Sustainable forest management and forest certification, payment for forest environmental services, and carbon credits can also be valuable tools that help to reduce forest fires in Viet Nam. These measures need to be considered, especially in the context of the increased areas of forest plantations.

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Sampling on a burned area to gather scientific evidence.
Photo: Bambang Hero Saharjo

3.3

Law enforcement to control land and forest fires in Indonesia

Bambang Hero Saharjo

"Enforcement of court case judgements has helped to reduce the number of uncontrolled fires, but without scientific evidence, the cases are very difficult to win."

Introduction

In Southeast Asia, land and forest fires are very common, either intentionally set or due to negligence, causing adverse effects to land, resources and ecosystems (Saharjo 2022). Both smallholders and industrial agribusinesses use fire to prepare land for subsistence and economic activities such as converting forest to permanent agriculture or plantation crops. The negative implications of fire include regional transboundary haze pollution, an increase in greenhouse gas (GHG) emissions, and a reduction in the productivity and sustainability of peatlands, notably by reducing biodiversity and storage of terrestrial carbon. Land and forest fires cause damage to natural resources that is not only biophysical; the economic values of environmental services may be lost and may even be irreversible.

In Indonesia, the use of fire as a land management practice is regulated by law to counteract its illegal and excessive use, which is often the cause

of unwanted wildfires. However, it is often difficult to determine the exact origin of ignition. Perpetrators usually cover their tracks carefully, leaving little evidence, and judiciary processes by the police and other agencies take considerable time. Law enforcement has benefitted from the evolution of methods for monitoring fire incidents, using satellite imagery supported by field verification. This has helped to reveal the culprits behind fire incidents, who can then be sentenced to pay fines and compensate for the environmental losses they have caused, following trials that are based on scientific evidence.

Tracing the cause of fires

The causes of fire in Indonesia, as elsewhere in the tropics, are primarily anthropogenic, either accidental or deliberate (Bompard and Guizol 1999; Bowen et al. 2000). However, the extent of human ability to change fire regimes and manage fire remains somewhat uncertain. A key component to changing fire regimes in the tropics is to identify the sources of fire and the main land use/land cover classes associated with fire (Cattau et al. 2016).

Government Regulation No. 4 of 2001 (Article 17), and Law No. 32 of 2009 on protection and management of environment (Article 69, Paragraph 2) state that using fire to clear land may be carried out only by indigenous communities, and only where the fire does not spread to neighbouring land that does not belong to them. Meanwhile, the use of fire by private companies is permitted only for eradicating pests and disease, and only following authorization from official authorities, as regulated in Law No. 41 of 1999.

Establishing who is responsible for a fire remains highly contested (Dennis et al. 2005; Page et al. 2011). It often results in a chain of finger-pointing, with no clarity as to the cause of the fire, including those in rainforest (Goldammer 1991). Originally, the Indonesian government blamed smallholder shifting cultivators for wildfires. Later, however, it claimed that wildfires were more likely caused by large companies using fire to open up land for commercial oil palm, pulpwood and timber plantations. Some of these practices were supported by government policies and incentives (Brown 1998; Page et al. 2011).

Although some large landholders clear land using mechanical means, many use fire, which can escape beyond its intended boundaries. Burning to clear land has been a traditional practice of smallholders and indigenous groups, but there is evidence that in the past this use of fire was relatively small scale and well managed (Tomich et al. 1998; Bowen et al. 2000). However, this is likely not the case today. The scale of land cleared by fire has expanded, with increased use of burning by both smallholders and by larger-scale rubber and oil palm concessions (Stolle and Lambin 2003). Both smallholders and large-scale farmers have been seen as responsible for causing wildfires (Stolle and Lambin 2003; Page et al. 2011). Increasingly, the clearing of land for plantations is considered the main cause of wildfires, such as the 1997–98 blazes that were the worst in Indonesia's history. They burned almost 11 million hectares (FPCI 2021), and accounted for one-quarter of total global carbon emissions at the time.

Fire regulations and management

Activities that control land and forest fires follow Government Regulation No. 45/2004 on Forest Protection, amended under Government Regulation No. 60/2009. Regulations specific to fire are included in Chapter III: Forest Protection from Fire (Articles 18–31). This is divided into Part 1, general; Part 2, fire control, including (i) prevention, (ii) extinguishing, and (iii) post-fire handling, which includes rehabilitation of burned land and law enforcement; and Part 3, crime and civil responsibility.

Many efforts to prevent forest fires have been carried out, by individuals (including shifting cultivators), private companies and the government (Saharjo 2022). Government-led approaches have included awareness raising with communities through education and training, but unfortunately, many of these activities have failed due to a lack of coordination and of long-term commitment of resources.

Where fire prevention is not successful, the resulting wildfires must be controlled. Companies may try to do this themselves, or with support from other parties, such as Indonesia's forest fire brigades (*Manggala Agni*). However, if extinguishing the fire takes days, this raises the question of why the fire became so uncontrolled, when companies are supposed to reduce the threat of fire in accordance with applicable regulations. In such cases, it is necessary to undertake an investigation of the burned area to discover if the fire was set intentionally, if its spread was due to negligence, and which individuals or corporate actors caused the fire.

Those responsible for the fire must then work to restore the damaged environment. The recovery process, or post-fire management, must be carried out not only on burned land but also on the broader ecosystem. This is because fires result in the release of GHGs and cause ecological imbalances in the burned area and beyond,

Field verification through sampling, photography and measuring peat. Photos: Bambang Hero Saharjo.

especially on peat. In addition, restoration must be carried out immediately in order to mitigate the fire's negative impacts.

Collecting scientific evidence

According to the Decree of the Chief Justice of the Supreme Court No. 36 of 2013, to prove that a fire has occurred and therefore caused environmental damage, it is necessary for the prosecution to provide scientific evidence about the fire. For this reason, it is necessary to trace the source of the fire. This is done by studying satellite imagery and by analyzing samples taken on burned land at an accredited laboratory; the samples are then compared with controls and quality standards in accordance with Government Regulation No. 4 of 2001. Without scientific evidence, judges cannot make decisions.

Whether fires occur on community land, or land owned or leased by a corporation, scientific evidence is needed for use in the trial process, including information about any pollution and environmental damage that resulted from the fire. Data is collected in two ways: (i) through use of satellite imagery; and (ii) by field verification, including analysis of soil samples. Confirming that a fire occurred and determining what caused it are not always easy to do, especially if the fire happened several years ago.

Satellite images

A combination of low- and high-resolution satellite imagery is used to ascertain the extent of fires, and can help to assess whether a fire was intentional and if its spread was due to negligence. Images from low-resolution satellite sensors allow burned areas to be detected, and if overlaid on a company work map or other map, they can illustrate the ignition site and spread. Data on high-temperature events (representing active fires) can provide an indication of fire occurrence.

Nowadays, law enforcement is supported by the availability of high-resolution Sentinel satellite imagery from the European Satellite Agency. These images identify the location of active fires, which is very helpful in ascertaining the source of fires, and can reveal fire incidents from previous years, as an example see figure 1. Other instruments — such as Google Earth, Nullschool and Worldview — allow users to reconstruct events in sequence to see if a fire occurred in a previous year but in an area that has since been replanted.

Field verification

It is necessary to confirm findings from satellite data through a process of field verification, with representatives of the company or the land owner present as witnesses. This verification process doesn't just look at the area burned, but also evaluates the broader agroecosystem, such as forest types and staple crops growing in the area. In addition, it assesses the fire control facilities

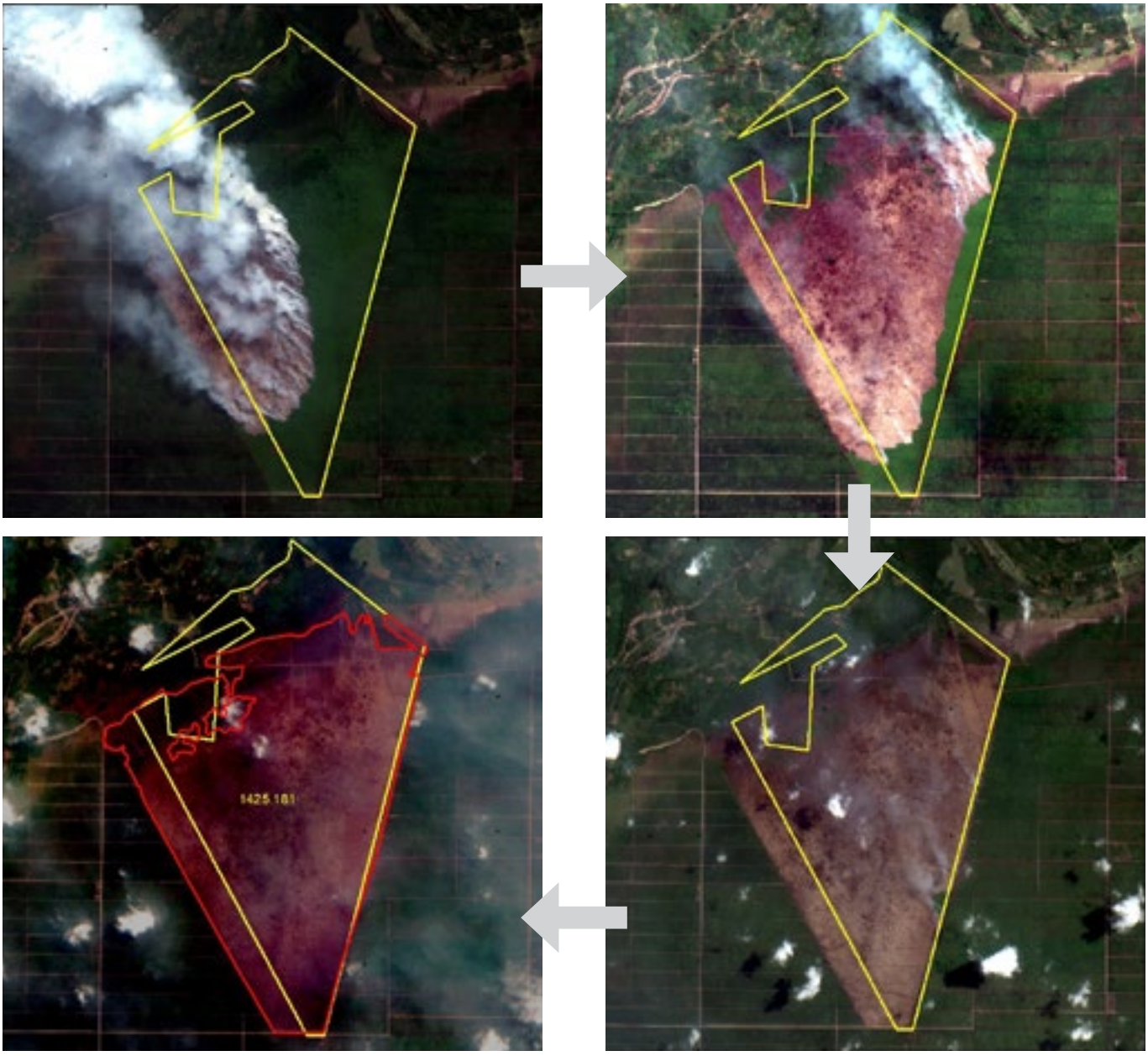

Figure 1. Tracking a fire in Jambi from soon after ignition using images from a Sentinel satellite. The yellow line indicates the boundary of a company's land, and the red line shows the limits of fire damage. Source: RFMRC-SEA

and infrastructure (in the case of a company) available to control fires, as required by applicable laws and regulations. For example, Regulation of the Minister of Agriculture No. 5 of 2018 (Article 17) stipulates that a team of 15 firefighters is needed for a plantation area of 1,000 ha, a team of 30 in areas of 1,000–5,000 ha, and a team of 45 in areas of 5,000–10,000 ha.

In addition, samples are collected for analysis in a laboratory. These can include burned soil/peat from surface and subsurface layers, and partially burned woody matter and ash (if any still remains), along with soil/peat from unburned areas for use as a control in comparing the changes. Also assessed are any vegetation regrowing on burned areas, peat thickness and groundwater depth. Field verification can be repeated as many times as required, even during the judiciary process, if more evidence is required.

A list of the samples taken during field verification are included in an official report. The report is signed by all parties, including company staff, land holders,

investigators, experts, and representatives from other relevant agencies who were present and witnessed the sampling. The investigator takes the samples to a laboratory for analysis to ascertain the impacts of the fire by comparing them to the available quality standards.

The judicial process

Cases of land and forest fires caused by communities are handled by the police, whereas the Ministry of Environment and Forestry adjudicates in corporate criminal cases and in civil lawsuits related to environmental losses. When cases are brought to court it can be difficult for the prosecution to accurately determine the answers to many questions. These include whether a fire actually occurred, and if so, when and where it started, if monitoring was carried out, , if the fire was extinguished properly, and whether the fire control facilities and infrastructure were adequate according to applicable laws and regulations. Other questions relate to what happened in previous years, what the motive was (if the fire was deliberately set), what economic and ecological damage was caused, what the cost of rehabilitation will be, and who should be responsible for paying that cost. To answer these questions, field verification data is cross-checked with satellite information, and the results are then overlaid on a company's work map.

Data obtained from samples are analyzed in the laboratory and then included in an expert certificate. Based on the information in this certificate, investigators conduct an examination to confirm that the fire did occur; to assess its origin, extent and impacts; and to ascertain whether it was intentionally set or occurred due to negligence. The file including all documentation is sent to the public prosecutor, who submits it during the trial. If there is still insufficient evidence, the police may need to undertake further investigations. During the trial, the defendants, through their lawyers, usually try to refute the evidence.

Examples of successful prosecutions

Haze pollution caused by fires has occurred for years, and was particularly bad in 2015. That year, more than 50 Indonesian companies were found guilty of causing fires that led to the haze that blanketed Southeast Asia (BBC News 2015). For the first time, the government began to revoke the licences of those companies found responsible, and although only a few companies have been named, the locations of 30 of the 56 companies that were punished are known.

In 2019, in an instance of a zero-tolerance enforcement approach against concession holders, an Indonesian court ordered palm oil company PT Arjuna Utama Sawit to pay the equivalent of USD 7.1 million in fines to the Ministry of Environment and Forestry and USD 11.5 million in compensation for environmental damages. This was in response to fires that razed 970 hectares of forest in Katingan District, Central Kalimantan province (Jong 2019). The company is a supplier to the Musim Mas Group, which has committed to a "no deforestation, no peat and no exploitation" (NDPE) policy to ensure the sustainability of its palm oil supplies. The group holds a concession to manage 16,600 hectares in the district.

Conclusions

Based on data tracking using satellite imagery, the source of fires and the distance they spread until they are extinguished can now be assessed with more certainty. This information is confirmed through field verification, a process that includes establishing whether a company has adequate fire control measures. The results of laboratory analyses of samples taken from burned and unburned locations help determine the impacts of fire on the soil and vegetation, the level of smoke pollution, and any other environmental damage caused. All of this scientific evidence becomes the basis for a court case and for a judge to make a decision about companies or individuals that are accused of being responsible for the fire. If the defendant is found guilty, the court will also then decide what restoration work is required and how much compensation must be paid to cover the broader costs of air pollution and ecosystem damage.

Since the enactment of Law No. 32 in 2009, and the use of evidence from satellite images and other instruments, most of the prosecuted cases have been won. There are still fires in palm oil plantations in Sumatra and Kalimantan, but their numbers have been greatly reduced: from 1.6 million ha in 2019 to 300,000 ha in 2021. This is due to vigorous legal action taken against companies, whether the fires were started deliberately or accidentally (FCPI 2021).

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3.4

Fire around the Doi Chang Pa Pae community. Photo: Buncha Dupunu Muharr

Combining community management of fire and water in Thailand

Veerachai Tanpipat, Royboon Rassameethes, Kobsak Wanthongchai, Prayoonyong Nhuchaiya, and Jittisak Yodcum

"Effective fire management is integrally linked to improved water management following a holistic, ethical and truly participatory approach."

Introduction

Fire has long been used in Southeast Asia to clear land and to facilitate hunting and the harvesting of non-timber forest products. Fire is also still used in slash-and-burn farming, but less often as farmers adopt rotational systems and agroforestry. However, increasing economic and climate change pressures mean that many natural forests have been permanently converted to agriculture, or now frequently burn. Wildfires are a major cause of forest degradation and biodiversity loss.

Smoke haze from fires is also detrimental to human health and livelihoods. Biomass burning is the dominant source of outdoor air pollution, contributing to premature mortality in the Lower Mekong region (Lelieveld et al. 2015). Poor air quality from smoke haze has become a national issue. A Clean Air Act is currently being considered by the House of Representatives, but further awareness raising is clearly needed.

A community group clearing dead undergrowth that could ignite and cause a wildfire. Photo: Buncha Dupunu Muharr

Smoke haze has also become a transboundary issue, from northern Thailand to southern China and Taiwan (Lin et al. 2014), so international efforts are also required to solve the problem, including more intensive efforts to reduce the number of wildfires.

A no-burning policy was introduced in Thailand in 2013 to tackle the problem. No-burning periods — at different times between January and May — were set by the governors of 17 northern provinces (Panyakam and Pongsawat 2021). This had only a limited impact, however, as local communities continue to use fire. Furthermore, mixed deciduous and dry dipterocarp forests are fire-dependent ecosystems, and no-burning policies would have negative impacts on their structure (Goldammer and Wanthongchai 2008).

An ethical approach

For effective fire management, it is crucial to have sustainable livelihoods. Community development must include adaptation and improved disaster resilience by integrating community-based fire and water management. This requires a holistic approach such as the concept of the "land ethic" (Leopold 1949), and the "sufficiency economy" of Thailand's former King Rama IX Bhumibol Adulyadej (Mongsawad 2010).

In Thailand, most community development involves the "sufficiency economy" concept in some way, including good practices in water resource management. Essential to the concept are multifunctional agroforestry systems that provide a wide range of economic, sociocultural and environmental benefits throughout the year. In Thailand, this is known as "three forests and four benefits" — the three forests are edible, usable and profitable; and the four benefits are food, other resources, income and conservation.

Community-based management of fire and water need to develop together and to integrate both indigenous wisdom and scientific knowledge. Measures include integrating modern practices of prescribed burning and thinning with cultural burning, and use of traditional practices along with new technologies.

Integrated forest fire management

This involves communities in using fire in land-use systems in safe and environmentally benign ways that prevent or control excessive burning and unwanted wildfires. It brings together best practices regarding fire ecology, fire management and social issues. Its participatory approach means that local people are involved in problem solving and local fire processes, and are supported by government agencies and NGOs. The successful participation of local communities depends greatly on strong local leadership and education.

Community-based fire practices in Southeast Asia are still limited, however. To develop integrated forest fire management in a given area, communities must be involved in all processes and must have a good understanding of fire ecology in order to ensure that

fire management plans will be adopted and effectively implemented. Unless local people agree to and participate in a plan, it will be impossible to sustain. Farms and forests — and the food, timber and non-timber forest products they provide — are all susceptible to burning by local people as part of traditional practices. Burning activities must be discussed, and be supported by science-based information, in order for fire management plans to be adopted and sustained.

Community participation

King Rama IX's concept of "connect-understand-develop" guides sustainability efforts. It underlies the need to understand every dimension of a particular area, both physical and social. Using this holistic approach, the first and most important task is to establish trust with local people before any process begins. That requires sincere and open communication. Moreover, strong community leadership is also crucial, and leaders must be committed to the approach. This commitment, which is often missing from sustainability initiatives, is the main driving force for success.

Only after trust is established can activities begin, including the collection of field data, remote sensing images, digital topographic maps, and weather and climate data. A range of technologies and tools can be used to gather information on soil and water, and to determine water demand and supply. The three main issues to address are water security, food security and community economy. The use of public-private-people partnerships (PPPPs) can help integrate soil, water and forest management and agriculture. With better incomes and livelihoods within a community, there is less demand on forest resources, and fewer fires. PPPPs build capacity and facilitate community networks and help to expand implementation from the individual level to the community, sub-district and river-basin level (HAII 2016). As of December 2021, there were PPPPs in 1,816 villages throughout Thailand, with 60 core communities within 19 river basins.

Participation is key to developing community-based fire management (FAO 2011), which includes open burning and fire protection (Wanthongchai et al. 2021). Community rules and regulations must be agreed to and accepted, so that everyone in a village will abide by them. This article discusses examples from four communities in northern Thailand (Figure 1): the Ban Huay Hin Lad Nai community; the Lao River Basin Community Network (Wieng Pa Pao District, Chiang Rai Province); the Ban Huay Pla Lod community (Mae Sod District, Tak Province); and the Ban Doi Chang Pa Pae community (Ban Hong District, Lumphun Province).

Ban Huay Hin Lad Nai community

This Karen community in Khun Chae National Park agreed to land-use zoning to manage their forests and other resources. This led to sustainable farming and to efficient and effective management of forest fires. Initial support came from the Royal Project in 1982, following Amnesty Order #66/23 in 1980. Later, many organizations

Figure 1: Locations of the four communities

Light green: Ban Huay Hin Lad Nai community and the Lao River Basin Community Network, Wiengpapao District, Chiang Rai Province; Red: the Ban Huai Pla Lod community, Mae Sod District, Tak Province; and Blue: the Ban Doi Chang Pa Pae community, Ban Hong District, Lumphun Province. Source: Google Earth

and institutions provided funding and support, thanks in part to the work of a strong local conservation leader, Preecha Siri, who received the UN Forest Hero Award in 2012.

To manage forest fires and smoke haze, the community adopted integrated forest fire management, supported by government authorities, researchers and NGOs. Integrating local knowledge and wisdom with scientific technologies and innovation helped people develop an effective fire management plan. The community established a committee to debate policies and make decisions on activities related to forest areas and resource use. For example, community members who wanted to cut down trees to build a house would need permission from the committee. The community also changed from shifting cultivation to rotational farming, where villagers divided planting plots into sub-plots in annual rotations, leaving some areas for natural regeneration and recovery. All plots are mapped and recorded in a database to prove that farmland areas are not expanding.

Through partnerships, participatory processes, acceptance and cooperation, the community has developed and taken ownership of specific action plans. This allows for sustainable agriculture practices while conserving natural resources and preventing forest fires. Moreover, the community has established a fund, with money earned from selling forest products such as bamboo shoots and honey, to manage forest fires.

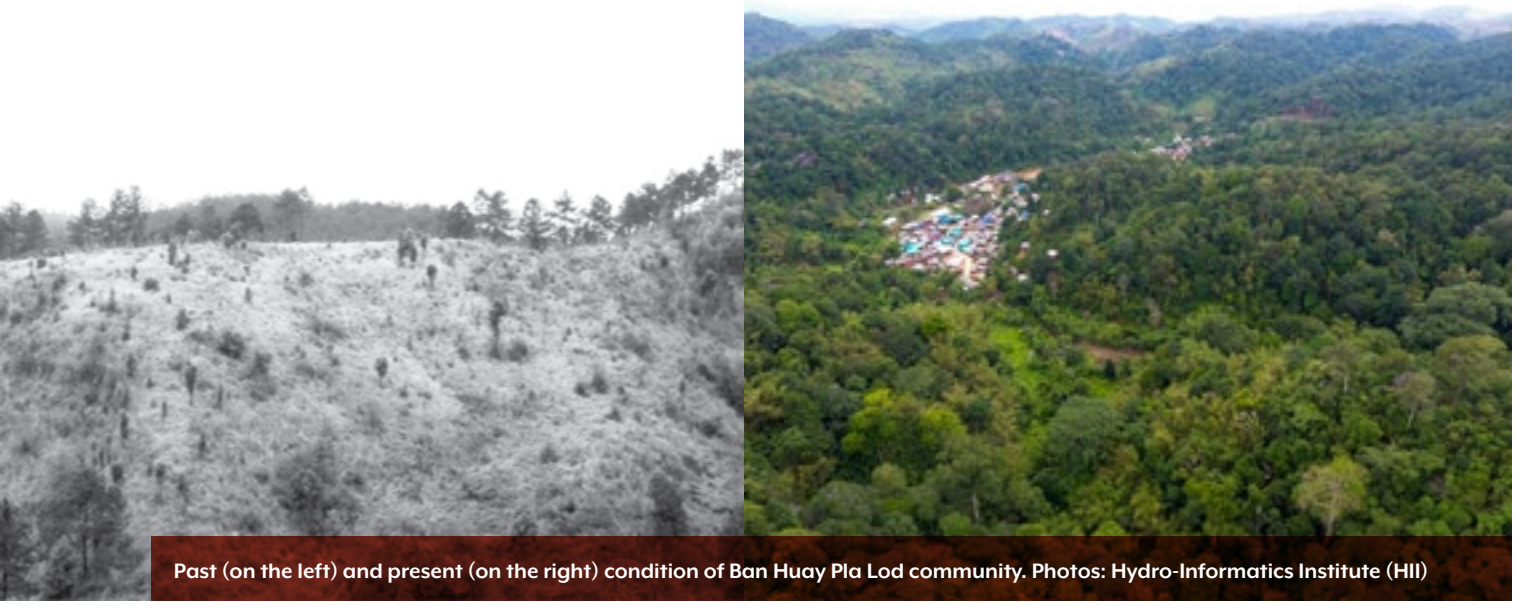
The fund is used to buy tools and equipment for the construction of firebreaks, to pay for fire patrols during the peak wildfire period (between January and April), and to buy food for firefighters.

A key strength of the community, and one that has contributed to the success of forest fire management, is the incorporation of local knowledge into the conservation of natural resources. This includes knowledge of sustainable agriculture, indigenous vegetation, the importance of biodiversity, and ancient traditions that have been passed from generation to generation. The community members are also open to learning about new technologies, and have adopted a mobile phone app that alerts them to nearby forest fires using satellite data from NASA's Fire Information for Resource Management System (FIRMS).

The community developed a map and database of their natural resources, classified according to forest type and land-use type, and detailing firebreak locations, ecotourism locations and other areas. The community participates in training and capacity-development activities organized by the government and civil society organizations, and plays an active part in knowledge and experience exchange networks that enable them to remain up to date on the current situation.

Lao River Basin Community Network

This was established in 2005. The network is supported by the Utokapat Foundation and the Hydro-Informatics



Past (on the left) and present (on the right) condition of Ban Huay Pla Lod community. Photos: Hydro-Informatics Institute (HII)

Institute (HII) to apply science and technology to managing water, forests and natural resources. Communities receive funding and support as long as they fully participate and learn by doing. It operates under a programme that reduces the risk of forestry-based disasters and builds resilient livelihoods.

This has led to four main outcomes:

1. establishing the network, which now manages water, forests and natural resources in an area covering 256 km² and, including 41 communities in four sub-districts;
2. construction of 2,528 check dams that provide water to 14 communities, 881 households and 2,740 people;
3. a programme that promotes the production of organic tea, coffee, herbs and vegetables, adding to household income; and
4. the la-on-hug-nam-lao youth group, which applies science and technology to collect data, report on the water situation and maintain a disaster monitoring system.

A community fund sustains all activities, including the youth group, without any financial support from government agencies.

Ban Huay Pla Lod community

In 1974, King Rama IX visited the community and urged them to restore forests using the "three forests and four benefits" concept. The people began to plant coffee instead of opium poppies. In 1981, the community became a part of Taksin Maharat National Park; this caused conflicts due to the loss of land-use rights. In 2008, Utokapat Foundation, under the Royal Patronage of H.M. the King as well as HII, started working with the community. It introduced upstream forest rehabilitation and community water resource management, and applied science and technology to manage water, forests and natural resources more effectively. This has led to massive reforestation and improved land management during the past 14 years.

The community conducted a participatory field survey to map water resources (Figure 2) and plan for the management of soil, water and forests. A forest restoration process was also initiated to recover and increase water resources for consumption, agriculture and power supply, and 400 check dams were built to increase soil moisture. People also planted coffee and vegetables, which provided income, as well as trees for shade. They improved water management through integrating science, technology and engineering to better understand their water supply and demand.

HII helped community members design a crop rotation calendar (Figure 3) to meet water and market demands and generate higher incomes throughout the year. The community also developed a sustainable land-use management plan, after zoning by land cover (Figure 4). This was possible using geoinformatics technology and by achieving agreement from all community members through many meetings, discussions and voting processes.

Figure 2: Water resources map prepared by the Ban Huay Pla Lod community. Source: Hydro-Informatics Institute (HII)

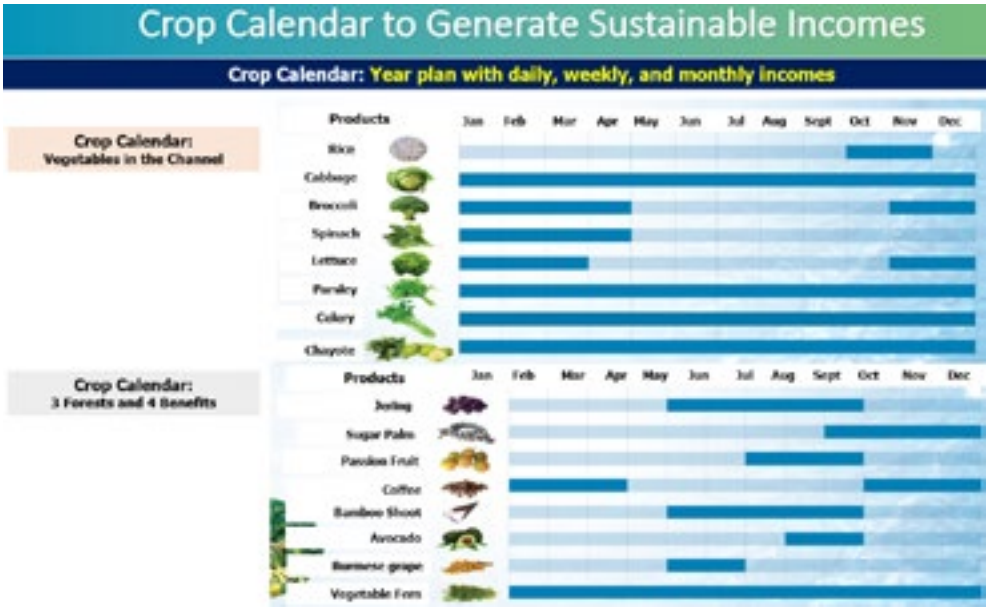


Figure 3: Ban Huay Pla Lod's crop rotation calendar. Source: Hydro-Informatics Institute (HII)

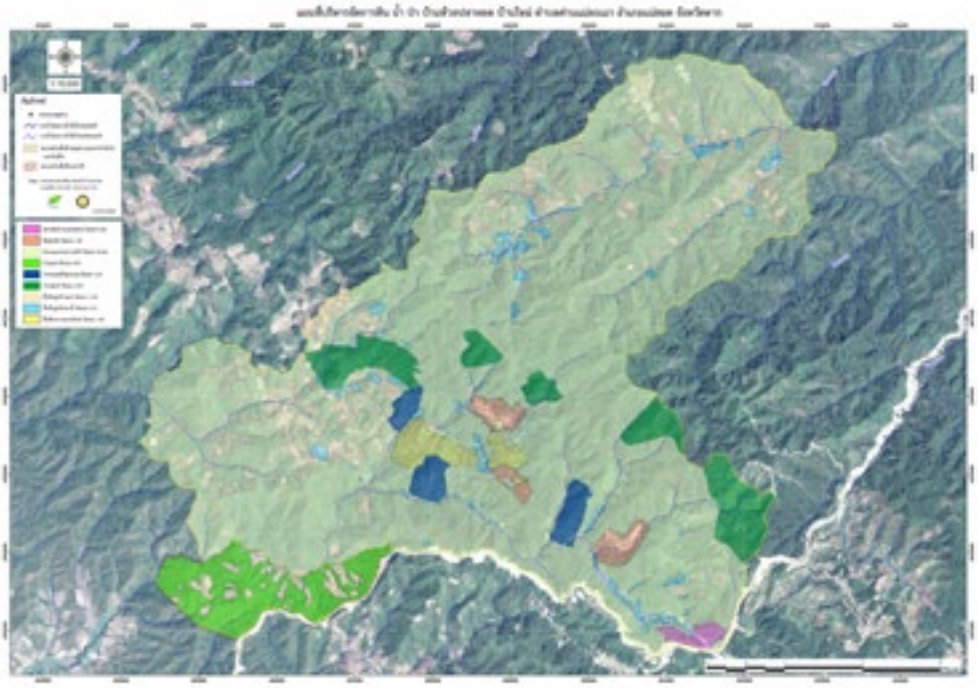


Figure 4: A land-use zoning map prepared by the Ban Huay Pla Lod community, with technical support from HII. Source: Hydro-Informatics Institute (HII)

Ban Doi Chang Pa Pae community

This is an indigenous community where rules and regulations have been agreed to and applied. In addition, the SEA-HAZEMON system monitors air quality; its low-cost sensors are installed in the mountains and monitored by local youth with permission from the village committee. This supports faster initial attack of fires through cooperation with the local fire control station. In addition, a rotatable thermal camera and high-resolution CCTV will also be set up. These measures show the community's adoption of innovative means to reduce fire risk by integrating indigenous wisdom with modern knowledge and technologies.

A simple and low-cost unit to monitor air quality, installed by the Ban Doi Chang Pa Pae community. Photo: Buncha Dupunu Muharr

Conclusions

Integrating community-based fire management and community water resource management provides a useful way to prevent the ignition and spread of forest fires in Thailand. This follows the Thai expression that "where is more water there will be less fire." More water also means more ways to generate income, which will improve community livelihoods and help sustain a community-based approach to fire and water management. Without sustained income sources, any community management initiative will fail when funding ends, as seen with payment for ecosystem services; for example, in Mae Sa Watershed (Wongsa 2015). With sufficient year-round water supply, local people have more cash crops and rotation periods to select from, and more flexibility to adjust to market needs. With higher income, they are also much less likely to go into the forest and start fires. In addition, increasing water in the landscape through the use of check dams creates a "wet belt" that acts as a firebreak.

Making integrated management work over the long term required structures and agreements that took time and patience to establish. These include measures for community forest conservation, land-use management, zoning, sustainable management practices, community regulations, penalties for breaking community rules, sustainable incomes, community markets, a community fund, and common rights. This article shows that communities can be supported to develop and maintain sustainable practices that reduce the risk of wildfires while improving water availability, air quality and income, and that with additional revenue streams, they can become self-sustaining.

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The forest and land fires control brigade of Kubu Raya forest management unit.
Photo: Teguh, FMU Kubu Raya

3.5

Forest management units and local innovations for fire prevention in West Kalimantan, Indonesia

Georg Buchholz, Jumtani and Gusti Hardiansyah

"Local foresters, together with local communities, are the best agents for fire prevention in West Kalimantan."

Introduction

The Government of Indonesia initiated a substantial reform of fire prevention approaches immediately after the devastating forest fires of 2015 and 2016. It was based on lessons learned from integrated fire management initiatives over the previous decades. Building on national Regulation 4/2001 regarding the Control of Environmental Damages and Pollution Related to Fires, the Ministry for Environment and Forestry enacted Regulation P.32/MenLHK/Setjen/Kum.1/3/2016 on the Control of Forest and Land Fires. This new regulation specified that the newly operationalized provincial forest management units (FMUs, *Kesatuan Pengelolaan Hutan*), would play key roles in fire prevention. The new regulation also stipulated that in addition to improving coordination among stakeholders, task forces at the FMU level, called forest and land fires control brigades (*Pengendalian Kebakaran Hutan dan Lahan*) were to be established.

Based on these regulations, a Grand Design for Forest and Land Fire Prevention 2017–2019 was defined and elaborated to guide national-level investments in fire management by the Ministry for National Development. The Directorate for Forest and Land Fire Control of the Ministry of Environment and Forestry, as well as national institutions such as the Meteorological Service, Disaster Management Agency, and Ministry of Agriculture, were instructed to implement provisions of the regulations, and to coordinate actions at the national, provincial and local levels.

Building on this framework and on a sustainable landscape-based management approach, the Indonesian-German Forests and Climate Change Programme (FORCLIME) supported the Provincial Forest Management System in West Kalimantan province and local stakeholders in fire prevention from 2017 to 2020. The programme also empowered FMU personnel to become competent facilitators, encouraging communities to develop and strengthen their livelihoods through agricultural or agroforestry techniques and land-use planning, without the use of fire. The technical approaches applied were adapted from successful experiences by various organizations in a range of locations, and incorporated local innovations developed at Tanjungpura University in Pontianak. Alongside fire prevention techniques, the programme promoted dialogue with communities and assistance for them to establish permanent agriculture and agroforestry as a means of reducing the use of fire to clear land, which is the main cause of wildfires and smoke pollution. This article summarize lessons learned from this programme and offers recommendations for fire prevention in Indonesia and beyond.

Fire prevention in the forest management unit of Kubu Raya

The forest management unit (FMU) of Kubu Raya regency covers 317,402 hectares (ha) over seven sub-districts (*kecamatan*). Almost 75% of the area (235,991 ha) is peatland, and its specific fire hazard characteristics are the main challenges to fire management in the FMU. See Figure 1. The main mandate of FMUs is to manage state forest land, but they also support fire control in non-state areas outside of these lands (Kubu Raya FMU 2019). The hazard characteristics of the peatland in Kubu Raya FMU were the reason that it was chosen by the provincial authorities as the intervention area for the FORCLIME programme.

Through cooperation with FORCLIME and Tanjungpura University, the institutional and technical capacities and facilitation skills of Kubu Raya FMU staff and its forest and land fire control brigade were improved. This notably enhanced their ability to formulate operational plans and carry out standard operational procedures (SOPs) to implement integrated forest and land fire prevention.

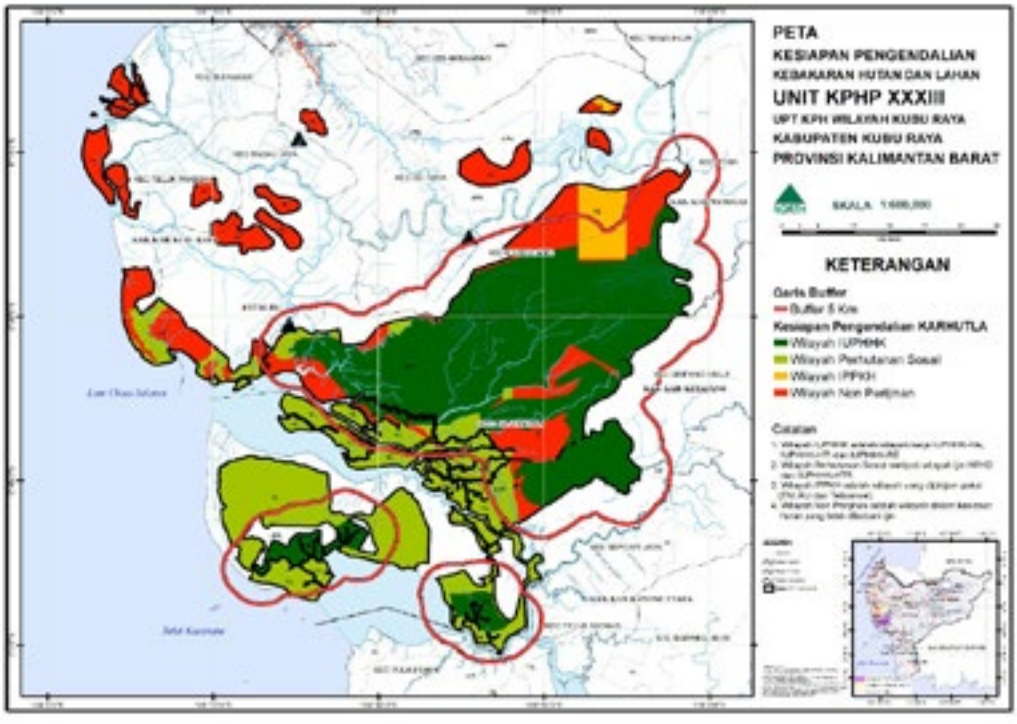

Figure 1: Fire preparedness map, Kubu Raya FMU. Source: FMU Kubu Raya

A forest and land fires control brigade of Kubu Raya forest management unit. Photo credit Teguh, FMU Kubu Raya

Besides strengthening the skills of technical staff, an important change in mindset was made in how the FMU staff perceive fire prevention. One innovation was the establishment of a "learning village" (*desa belajar*) programme in four model villages. It taught skills to community members in agroforestry, agriculture and ecotourism as part of a village development plan that excludes using fire to clear land. This programme used an integrated forest and land fire prevention approach that also increased income from alternative economic activities, without burning. Through the programme networking and cooperation were also built between communities and various government institutions at various levels. The approach is an evolution from previous integrated fire management approaches, such as the IFFM project in East Kalimantan some decades ago (Dennis 1999).

The provincial regulatory framework

The provincial Environment and Forestry Service is now more aware of the need to establish forest and land fire control brigades in each FMU, and to provide clear guidance on integrated forest and land fire prevention through operational planning and best practices. Local government policies on the prevention of forest and land fires, , have improved, and Provincial Government Regulation No 6/1998 on Forest and Land Fire Control has been reviewed and enacted. A provincial command centre for forest and land fire control was established in 2019, facilitating improved coordination among institutions, including Kubu Raya FMU. SOPs were developed to support the implementation of fire prevention and control activities. These included tools and operational guidance for FMUs and other authorities in the development of fire management plans and thematic maps on fire preparedness and fire hazards, in order to determine the priority of fire prevention activities.

Simultaneous work at the provincial and FMU level has also been instrumental in translating the lessons learned from field activities into provincial regulations. For example, Provincial Regulation No 6. 1998 was reviewed in 2020 by all stakeholders working on fire management at the local level. The review process increased the effectiveness of local actors at all stages of the prevention and management of forest land fires. This work culminated in the Directive and Provincial Guidelines for Fire Prevention (SK Kepala Dinas Lingkungan Hidup dan Kehutanan Provinsi Kalimantan Barat Nomor 223.I/DLHK-V/PP/2020).

Local knowledge hubs

Two important aspects of improving fire prevention are innovation and the creation of new knowledge. There is a need for local champions to adopt new practices. Local universities are key in generating and maintaining knowledge on fire prevention, and also for their work on local policies for forests and fire. Behavioural change is one of the goals of fire prevention and sustainable forestry activities, but this is a long-term process.

Universities provide consistent approaches and keep knowledge local, in contrast to many governmental

structures, which frequently rotate staff, leading to "brain drain." Additionally, senior university staff are often involved as advisors and service providers for the provincial and district authorities that play important roles in planning processes.

West Kalimantan is fortunate to have Tanjungpura University, with a forestry faculty that serves as a knowledge hub, educating current and future generations on fire prevention. Its curriculum includes forest protection, use of fire equipment and firefighting techniques, and incorporates locally generated experiences. Equally important is the university's innovative research and development work, such as that by Arman et al. (2015), as well as various tools and technologies, including several fire-extinguishing systems that are adapted to the challenging issue of controlling peat fires. One example is the Nyapar firefighting tool; research led to the development of the tool and to special nozzles to extinguish underground peat fires (Hardiansyah et al. 2016).

The university also has its own 19,622-ha forest (*KHDTK Untan*). This is used as a centre of excellence, a living laboratory and an education centre to share knowledge on forests, including fire management. It is also used to provide training for local communities, in collaboration with provincial environment and forestry agencies, and with the firefighting task force of the Ministry of Environment and Forestry (Hardiansyah et al. 2021).

Tanjungpura University is very active in organizing communities and improving their capacities in fire prevention. These communities have created fire task forces, and receive training in firefighting operations and how to use fire equipment such as the Nyapar tool. The university also provided six villages with fire equipment, and is drilling wells to support fire suppression efforts. The university also established a data and information centre, with locally adapted biophysical indicators for a disaster early-warning system for fire, food security and agriculture in real time.

The overall goal of this forest education is to demonstrate best practices and inspire people by showing how these practices can improve and scale up sustainable forest management activities. The university uses an interdepartmental approach. Implementation related to forest and land fire topics involves three faculties that are responsible for education and teaching, research and development, and community empowerment.

Indonesia benefits from having considerable experience in community-based fire management approaches (GFMC 2022b) and in national and regional policy dialogues (GFMC 2022a) since the 1990s. Furthermore, the country is home to the Regional Fire Management Resource Center – Southeast Asia (RFMRC-SEA), hosted by IPB University in Bogor, West Java province. This centre of excellence also serves as an national innovation hub, disseminating local innovations such as those developed at Tanjungpura University, and with a mandate for national and regional networking, capacity development and providing information. It is hoped that the added value of sharing and replicating experiences gained at the local level, as in this case, is taken up at national and

Nyapar fire equipment being demonstrated in a training session. Photo: Gusti Hardiansyah, Tanjungpura University

Mobile fire control equipment being moved to the fire location. Photo: Erwin, FMU Kubu Raya

international levels, with funding from either national or international sources.

Challenges

During local-level activities, several issues have become apparent that should be addressed.

FMU capacity. Some FMU staff lack the skills needed to gather information from communities, improve coordination with related government institutions and other stakeholders (including plantation companies and NGOs), and maintain networks of FMUs for sharing information and experiences. Most FMU staff are also not yet fully aware of the great potential for collaboration with communities to achieve forest conservation goals and community welfare through fire prevention activities. In addition, new staff lack the understanding and awareness of the need for close and daily contact with communities.

Local facilitation. Villages are dependent on facilitators who are often external and project-based, rather than facilitators who are part of permanent village structures or local government. This increases the possibility that villages will discontinue their work on fire prevention and alternative livelihoods once the facilitator has left.

Village-level planning and priorities. Village councils tend to prioritize physical infrastructure in development planning and do not see forest and land fires as an important issue. This is evidenced by the correspondingly small budget allocations from village funds, which also tend to be used for responding to fires and not for fire prevention. In addition, FMU activities at the village level related to the prevention of forest and land fires are often not well coordinated, meaning that projects overlap and money is wasted.

Recommendations

Forest management units would benefit from the following specific activities:

- Increase cooperation with other agencies to ensure that activities are planned in a way that simultaneously meets multiple objectives. This is particularly important given the need to optimize funding and to use it for fire prevention and not only fire suppression.
- Identify and make an inventory of all stakeholders working in the FMU area, and become familiar with their projects and land uses so that synergies can be explored and developed. Develop close coordination among FMUs, national fire suppression structures (*daerah operasi* – DAOP) and the National Board for Disaster Management, to share information, clarify roles and expectations, improve planning, and agree on SOPs for fire management.
- Pursue strategies to increase communities' ability to monetize sustainable alternatives to using fire. These strategies should include innovative visual materials to show people what they can do instead of burning, rather than telling people what they cannot do (which they already know).

Such prevention efforts would benefit from promoting water management in peatlands (e.g. canal blocking), agroforestry, land rehabilitation, alternatives to slash-and-burn agriculture, and improving access to markets for fire-free agricultural products.

- Institutionalize fire prevention, rather than fire suppression, as a priority through changes in the FMU system and the organizational structure. This should address the failings of other administrations and incorporate the specific objectives of FMUs in the underlying Indonesian context.
- Limit investments in fire suppression capacities, except for basic training and equipment. Instead, FMUs should increase and rely on cooperation with DAOPs, disaster management authorities, and the private sector.
- Undertake further technical training whenever and wherever possible. Discussions with the Peatland and Mangrove Restoration Agency and provincial task force leaders should continue, as capacity strengthening will improve the management of FMUs while also helping to eliminate some of the obstacles faced by the agency.

Although these recommendations are outside of the scope of direct activities of the FORCLIME project, community engagement is also important in fire management:

- Revise standard budget lines in village funding schemes to include fire prevention.
- Promote and subsidize agroforestry activities as part of fire prevention.
- Increase investments in improving water management (deep wells, channel management, etc.).
- Clarify tenure arrangements and village boundaries.
- Invest in community forestry management and in clear management arrangements for community land.
- Establish internal village structures for fire management and the wise use of fire (e.g. fire volunteers) and establish linkages with neighbouring villages for exchanging information on and experiences in fire prevention.

Furthermore, regarding information and knowledge management, it would be valuable for all concerned to strengthen linkages between local agencies and universities, and with national-level actors such as RFMRC-SEA.

Conclusions

Overall, it has become clear that local forest management units — together with local communities — are the best agents for fire prevention in West Kalimantan. Leaders of forest management units should be encouraged to take advantage of opportunities arising from the FMU system, which is a relatively new creation. This should include thinking creatively, being cautious about replicating old approaches, strategies and accepted norms in forest and fire management, and taking initiatives in brokering participatory processes to overcome challenges.

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Training in prescribed burning, Hetauda, Makawanpur, Nepal.
Photo: Sundar Sharma

3.6

Challenges in forest fire management in the Himalaya: experiences from Nepal

Sundar Sharma and Anil Pokhrel

"Participatory, community-based approaches to improve fire management are imperative."

Introduction

In Nepal, fire is used as a traditional tool for clearing and managing agricultural and pasture land. It is also used to facilitate gathering non-timber forest products and in hunting and herding. An analysis revealed that 58% of all forest fires were deliberately set, followed by negligence (22%), and accidental (20%) (Sharma 2010). Moreover, the country's diverse climatic conditions, vegetation, ecosystems, and socioeconomic and cultural settings result in a wide range of land use systems and diverse fire regimes and vulnerabilities.

Fires are a regular occurrence during the long and intense dry season, and have serious impacts, causing both ecosystem degradation and deterioration of already vulnerable social and economic conditions, especially in fragile Himalayan ecosystems. Forest fires destroy timber and non-timber forest products, reduce biological diversity, degrade soil

(inducing soil erosion), and increase the risks of floods and landslides. The haze from fires has also resulted in the closure of schools and airports and affected the country's important tourism industry. There is, however, no systematic collection of data on fire impacts on wildlife, medicinal plants, health, or on weather and climate from atmospheric brown clouds; the same is true in the South Asia region as a whole.

Each year in Nepal, on average, 200,000 hectares of forests are burned during the fire season from mid-November to May; 8 people die, 6 are injured, and 88 houses are destroyed (Bajracharya 2002). The number of reported fires varied considerably from 2012 to 2021, however (Figure 1), reaching an unprecedented level in the 2020–21 forest fire season, with 6,799 fires reported — ten times more than the previous season and three times more than the average in the previous eight years. The occurrence of forest fires is increasing, at least in part as a consequence of regional warming and extended dry spells (Sharma and Goldammer 2011) and of growing aridity and hydrological changes (NCVST 2009). There were many forest fires in March 2009, for example, causing huge plumes of smoke (Figure 2).

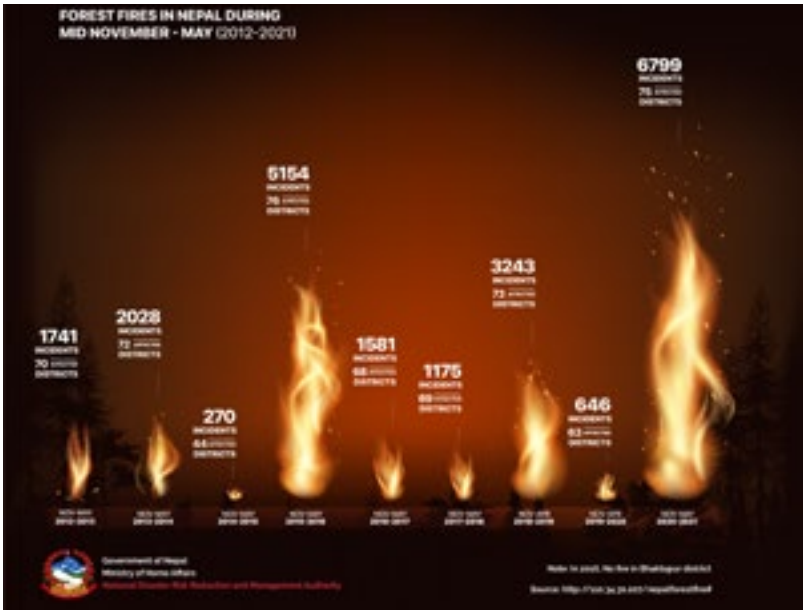

Figure 1: Number of forest fires in Nepal, 2012–21. Source: DoFSC/ICIMOD 2021

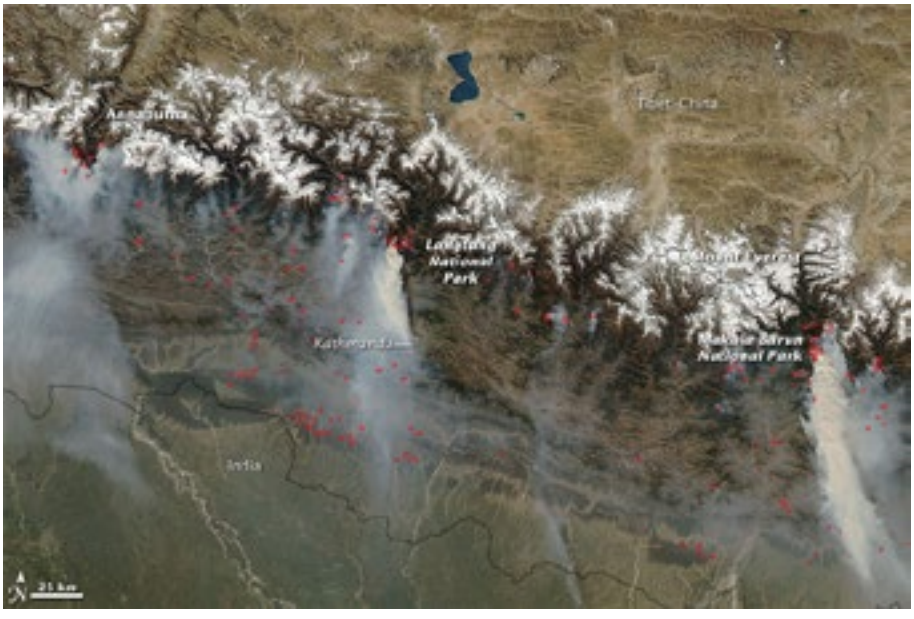

Figure 2. Large forest fires in Nepal on 12 March 2009.
Source: NASA Earth Observatory

Participatory planning for forest fire management in community forests. Photo: Sundar Sharma

Climate change interactions

Forest fires release particulate matter and gaseous emissions, causing atmospheric brown clouds, which are a major driver of regional climate change. The processes involved in the transport and chemical composition of smoke plumes associated with wildland fires are known, but further research is needed to enhance understanding of the fundamental fire-fuel-atmosphere interactions that govern plume behaviour. This behaviour is determined by fuel characteristics, fire behaviour, emissions, canopy structure, fire-induced and ambient turbulence, and basic atmospheric conditions (Heilman et al. 2014).

Nepal has the eighth highest per-capita rate of CO_2 emissions among least developed countries, primarily because of deforestation. Recent research suggests that if forest fires continue to increase, this could significantly increase glacial melt rates in the Himalaya, both by increasing the deposition of soot on glacial surfaces (reducing albedo) and by releasing aerosols into the middle troposphere (warming the atmosphere). The link between decreased albedo and increased snowmelt is well established, but the links between aerosols, middle troposphere warming, and glacial melt rates are more tenuous, although aerosols have been isolated as a likely contributor (Ramanathan et al. 2007).

Local initiatives

Community involvement has proved to be successful for sustainable resource management, and community-based fire management (CBFiM) could be the key to overcoming the recurring problems of forest fires. In Nepal, with no national forest fire management plan or programme until 2010, community forest user groups try to control fires in their own forests, despite a lack of planning, proper training and equipment. There is also a lack of local and national capability in fire management, including research, monitoring, early warning, assessment and facilitating cooperation.

One example of how to address these issues is the Three-Level Wildland Fire Management Project, which developed and implemented a district-level forest fire management plan, along with training of community forest user groups and local government members. It was implemented in Makawanpur District in 2007 by the Department of Forests (DoF) and the Global Fire Monitoring Center (GFMC) and was supported by the German government.

National level

The country's first forest fire management strategy was drafted during a national consultative workshop in Kathmandu, and after stakeholder consultation, it

was approved by the Government of Nepal in 2010. Responsibility for fire management fell under the National Disaster Risk Reduction and Management Authority (NDRRMA), which was established in 2019 under the Ministry of Home Affairs to protect human lives and property, to act as a central resource body, and to formulate national disaster management policies and plans. Responsibilities then cascade down to provincial, district and local levels. State disaster management committees under the chairmanship of the chief minister approve variation of the national plan depending on context. There are also 77 district disaster management committees coordinated by the chief district officer. At the local level, there are disaster management committees in all 753 municipalities.

NDRRMA is responsible for forest fire risk reduction and management. It received a significant budget for 2021–22 to undertake activities and programmes that will form the components of and basis for a comprehensive national strategy. These include training in forest fire awareness and risk reduction, design of comprehensive training curricula and e-modules on integrated forest fire risk management (in English and Nepali), and procurement of firefighting tools and equipment (hand tools, robotic firefighting equipment and fire trucks). In addition to training and providing equipment, activities include the revision of the 2010 forest fire management strategy, forest fire damage and loss assessment and risk evaluation, development of air pollution disaster management, and forest fire resilience action plans.

A great step forward in national fire assessment was the Forest Fire Monitoring and Detection System. It provides real-time information on the occurrence of and extent of damage caused by fires, and sends SMS messages and emails to concerned officials across the country (DoFSC/ICIMOD 2022). Operational since 2019, it was developed by the Department of Forests and Soil Conservation (DoFSC), with technical support from the International Center for Integrated Mountain Development (ICIMOD). With the help of fire risk zone maps and other fire monitoring tools, managers can now easily track fire-risk areas and develop fire management strategies (Figure 3). This has enabled efficient and effective decision making to minimize fire risk, such as allocation of resources to areas where they are needed.

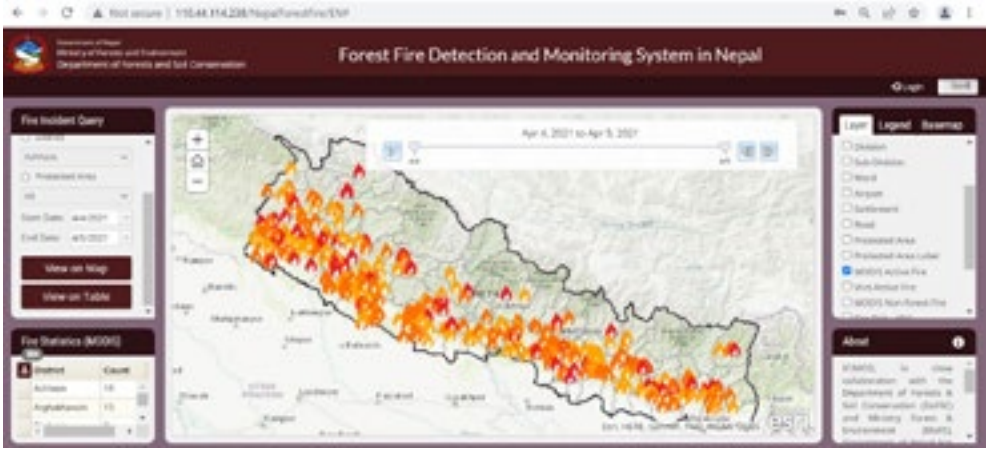

Figure 3: Forest fire detection and monitoring web tool, showing 584 fires detected on 5 April 2021. Source: DoFSC/ICIMOD (2021)

Regional initiatives

After the foundation of the regional South Asia Wildland Fire Network in 2007 (Sharma 2007), regional consultations were conducted in Nepal in 2012 and in 2016 on the development of a cohesive local-to-global fire management initiative: the Regional South Asia Wildland Fire Network (GFMC 2017). These consultations resulted in the following ten shared conclusions and recommendations, which are in various stages of realization:

- develop/strengthen national institutional bases for fire management, including national inter-agency coordination mechanisms, and academia and civil society groups;
- create/strengthen national fire management advisory committees under a government-based secretariat or a national fire management coordination unit, to convene national stakeholders in fire management and to develop national fire management policies;

Sharing experience in the field during the 2012 Regional Pan-Asia/Pacific consultative workshop in Nepal. Photo: Sundar Sharma

- establish an integrated fire management finance mechanism, to include financial resources from national sectoral budgets and international sources;
- provide adequate insurance for those involved in fire management (professionals, volunteers, community members) in case of injury or death;
- establish a Fire Management Resource Center in the South Asia region to provide monitoring, documentation, analysis, capacity building and advisory services in fire management;
- develop/enhance transboundary cooperation among South Asian countries within the UNISDR Regional South Asia Wildland Fire Network and the Pan-Asia Wildland Fire Network, for information and technology sharing, joint training, and improving preparedness and inter-agency operations for effective responses during wildfire emergencies;
- translate the EuroFire Competency standards and training materials into the main South Asian languages, and contribute to the finalization of the International Fire Aviation Guidelines and Manual of Common Rules for Fire Aviation, and consider their approval and application;
- consider implementation of the recommendations of previous regional and international meetings, conferences and summits;
- encourage Asia-Pacific countries to develop bilateral and multilateral projects and programmes to enhance fire management capabilities; and
- encourage active participation in dedicated thematic networks, including annual meetings and activities of the Pan-Asia Wildland Fire Network, the Global Wildland Fire Network, International Wildland Fire conferences, etc.

In addition, in the Asia-Pacific region, several expert consultations on the future needs of forest fire management have been held among the Regional Wildland Fire Networks of Asia (e.g. Sharma 2009) under the auspices of the UNDRR Global Wildland Fire Network (GFMC 2017).

Moreover, as a member country of the South Asia region, Nepal has continuously been involved (both as a trainer and trainee) in forest fire management training programmes organized by the Asian Forest Cooperation Organization (AFoCO), in cooperation with the Global Wildland Fire Network, since 2014. The programmes are mainly focused on fire safety and behaviour, fire prevention, fire inspection, fire information systems and fire suppression where community-based fire management is a priority.

Regional consultative workshop on cross-boundary cooperation in fire management in South Asia, Kathmandu, Nepal, 2016. Photo: Sundar Sharma

Conclusions

Nepal faces challenges in forest fire management that are aggravated by climate change, and there is an urgent need for financial, institutional and technological resources and for capacity development to effectively implement fire management. The problems of forest fires in the region are complex, and cannot be addressed at a single sectoral level. To overcome the country's limited capacity in fire management, there is a need to strengthen the human and technical resources of agencies and local communities that deal with fire prevention and response. In addition, transboundary cooperation in fire management is needed to share the most appropriate knowledge of advanced approaches in fire management. For this reason, a system of exchange of expertise in fire management between countries globally has been established: the International Wildfire Preparedness Mechanism (IWPM).

Policies and legal arrangements related to forest fire management include the Forest Fire Management Strategy 2010, National Disaster Risk Reduction Policy 2018, Disaster Risk Reduction National Strategic Plan of Action 2018–2030, Disaster Risk Reduction and Management Act 2017 and Regulation 2019, Forest Act 2019, and the Private House Reconstruction and Rehabilitation Relief Procedure damaged by Fire 2022. However, there are inadequate financial, institutional and technological resources and capabilities to effectively implement these measures. The National Disaster Risk Reduction and Management Authority (NDRRMA) coordinates disaster management, and the Ministry of Forests and Environment (MoFE) coordinates forest fire management, but there is no dedicated unit to deal with forest fire disaster risks.

The establishment of a Fire Management Resource Center for the South Asia region is recommended, to be hosted by NDRRMA in Nepal. This would coordinate with international institutions and provide monitoring, documentation, analysis, capacity building and advisory services in forest fire disaster risk reduction and management, and promote principles, norms, rules and decision-making procedures within an agreed guiding framework. It would enhance and strengthen bilateral, multilateral and international cooperation in wildland fire management, create synergies and share knowledge, technical and human resources among countries.

Local communities will benefit, first from reduced fire occurrence and severity. Participatory, community-based approaches to improving fire management are imperative (Sharma and Goldammer 2011). The proposed regional centre would strengthen local communities' capacity to cope with forest fires by helping them to address the consequences of climate change and fires that affect their livelihoods. When assisting countries in fire management planning, coordinated and collective action, and enhancing institutional and technological capabilities, emphasis will be placed on community-based fire management approaches, and on promoting education and awareness-raising programmes on fire prevention.

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Section 4

Africa

Photo, previous page: The presence of combustible material increases the risk of fire and fire propagation.
Photo: Harifidy Rakoto Ratsimba

4.1

Fire volunteers reducing the fuel load to slow the spread of a fire.
Photo: Melle Meivogel

A community-based approach to wildfire prevention in Ghana

Rosa Diemont and Tieme Wanders

"Through cooperation, people have learned that together, they could become responsible for reducing risks, and took active steps to prevent wildfire outbreaks."

Introduction

Forests in Ghana are increasingly influenced by human-induced fires. Until the 1980s, uncontrolled wildfires were relatively uncommon in the country, especially in the forest zone in the south. Many older farmers recall the extremely dry year of 1983 as the tipping point, when the country experienced devastating wildfires that destroyed forests and lives, villages and livelihoods. Since then, wildfires have become an annual phenomenon in Ghana's landscapes during the dry season, and decision makers must consider how to reduce their frequency and impacts.

Form Ghana is a forest plantation management company based in the central part of the country that produces timber and carbon credits for local and international markets. One of Form Ghana's land leases is within the Tain II Forest Reserve in Bono Region. Together with Form International,

Wildfire spreading towards the Tain II Forest Reserve. Photo: Rosa Diemont

the company developed the Forest Landscape Restoration Programme in 2017 to collaborate with neighbouring smallholder communities in improving local livelihoods. Most community land is managed under the traditional authority of chiefs and their families, and many people rely on farming as their sole source of income.

This article describes how a community based approach has reduced wildfire outbreaks by 78% between 2018 and 2021. From a situation in which wildfires were frequent, where nobody felt responsible and from which everybody suffered, people now make efforts to manage the risk and help to prevent wildfire outbreaks.

Fire in the landscape

The Tain II Forest Reserve lies within the Eastern Guinean lowland forest zone. It was once completely covered with dry, semi-deciduous forest that played a vital role in the lives of local people. Today, however, very little of the original forest remains, and human-induced degradation has led to vast areas of the reserve becoming bush land and savannah. Farming and annual wildfires have promoted the growth of the tall and fast-growing elephant grass (*Cenchrus purpureus*), which inhibits the natural regeneration of forest species. This grass is quick to ignite during the dry season (December to March), when humidity drops to below 10% in the daytime, and the Harmattan winds further dry out the vegetation; they can also severely limit visibility. The poor road network hinders rapid response to fires in remote areas. These elements combine to contribute to severe uncontrollable fires that further degrade unmanaged areas within and around the forest reserve.

In this lowland forest zone, fire is not a natural phenomenon. The wildfires that do occur all spread from fires that are intentionally set by farmers in the surrounding landscapes, and spread from there into the reserve. In Ghana, the use of fire is a longstanding practice by smallholders to clear land for cultivation, and is also used by hunters, herders and beekeepers, who are all often blamed for the fire outbreaks. In addition, it is often mentioned that local communities have limited knowledge of fire management, and the bylaws of many Ghanaian districts prohibit the use of fire during the dry season. However, the outlawing of burning and making this traditional practice illegal have not had the desired result. Throughout Ghana the risk of wildfires continues, threatening lives, farms and property. Furthermore, prohibiting the use of fire limits farmers' control over their land, and also creates conflicts between farmers and other occupational groups. To avoid punishment, each group blames the other for setting the fires.

More fires also create a vicious cycle that increases the risks of yet more wildfires. Farmers become discouraged from investing in perennial crops such as fruit and nut trees. When an area burns every year, farmers will plant only annual crops and harvest them before the dry season. This leaves farmland unmanaged after harvest, allowing wildfires to spread freely through the landscape.

Farmers were very unhappy with this situation, but felt that they could do nothing about it on their own. Only by acting together at a landscape level could they hope to make impactful changes.

Towards a grassroots solution

The Forest Landscape Restoration Programme brought together all the key stakeholders, including traditional authorities, three regional departments of the Ghana National Fire Service, and the Ghana Forestry Commission. In the initial phase of the programme participants soon realized that outlawing burning in the dry season was not the way forward, as fire is part of the way of life in farming communities. To counter the accelerating degradation and to stimulate forest restoration, incidences of fire in the area had to be reduced by increasing awareness and drastically changing the roles of people in wildfire management.

Since the *Control and Prevention of Bushfires Act* of 1990 was enacted, the regional offices of the Ghana National Fire Service have been responsible for fire management. They operate through a system of community fire volunteers who they appoint. These volunteers make daily patrols during the dry season and have the right to arrest offenders and report them to the police. However, the fire service does not have the resources to implement education programmes, or to help fire volunteers execute pre-fire-season prevention programmes and fight wildfires. All the responsibility for mobilization, organization and firefighting has been left completely to the volunteers themselves.

Importantly, the programme team found that traditional leaders — who in Ghana are the stewards of the land — were not involved in decision making regarding the appointment and operations of the community fire volunteer squads. This resulted in conflicts of interest, which reduced the squads' effectiveness at the village level.

For this reason, the first step of the programme was to engage with traditional authorities and community leaders. Together with them, the Ghana National Fire Service and the community fire volunteers developed an integrated community fire management project. They proposed and jointly agreed on structural changes, including the revision of local bylaws to allow farmers to use fire under certain conditions. These conditions are that a community must have trained, operational and equipped community fire volunteers who work according to a set of operating procedures.

The structural changes led to a significant shift in how everybody in the community perceived fire. Instead of fire being an outlawed and taboo activity, with punishments for those that used it, the programme could now focus on making people capable of and responsible for taking preventive measures to reduce wildfire risks and to use fire responsibly.

All the relevant authorities presenting the first jointly designed and aligned approach to fire management. Photo: Melle Meivogel

A signboard showing the current fire danger index. Photo: Rosa Diemont

Improving effectiveness

Working together, the participants developed an improved operational structure by adapting traditional working practices, and by adding new measures, such as the use of a fire danger index and allowing controlled burns that are regulated through a permit system.

In each volunteer fire squad, the appointed leader and a leader-assistant prepare a fire management plan that includes community activities to limit fire outbreaks in the coming dry season. They then present the plan to the village chief, who has to formally approve it and give the mandate to call people to action. Squad leaders are responsible for organizing volunteers, mobilizing farmers to prepare farms before the dry season, and undertaking other collective actions such as weeding the firebreaks.

Squad leaders trained by the programme in turn train volunteer squads and community members in topics such as being fire-wise, and the consequences of using fire. Key to the training was raising awareness in the communities of the new rules and regulations, and of the permit system for controlled burns. In the new system, the fire squad can give permission for starting a fire. If a farmer is granted permission to use fire, volunteer squads provide assistance to ensure that it is a controlled burn.

Their decision to grant permission is based on whether it is safe at that time, according to a fire danger index. The index is a score from 1 to 100 that is calculated according to a measure of vegetation dryness, air temperature, wind speed and humidity. Used worldwide, the global fire danger index was adapted to the Ghanaian environment and in the area is called the fire warning (*Egya Kɔkɔbɔ* in Twi, the common language in the area).

Through a WhatsApp group, weather conditions and the fire danger index are communicated every two hours to squad leaders by Form Ghana's operations centre. In turn, squad leaders post the index on fire notice signboards and spread the word, so the whole community is kept aware of the current situation and how it affects fire behaviour and fire risk.

In addition to the fire danger index, the fire notice board lists the squad leaders and fire volunteers, along with their telephone numbers. The board also displays instructions (in pictures) on what to do to get permission to burn and what to do in case of a wildfire.

Prevention, not suppression

There is no high-tech firefighting equipment available for suppressing wildland fires in rural Ghana, and water availability is limited in the dry season. Fire volunteers were trained in suppressing small to medium-size wildfires using hand tools such as beaters and rake hoes, but the programme focussed on prevention rather than suppression.

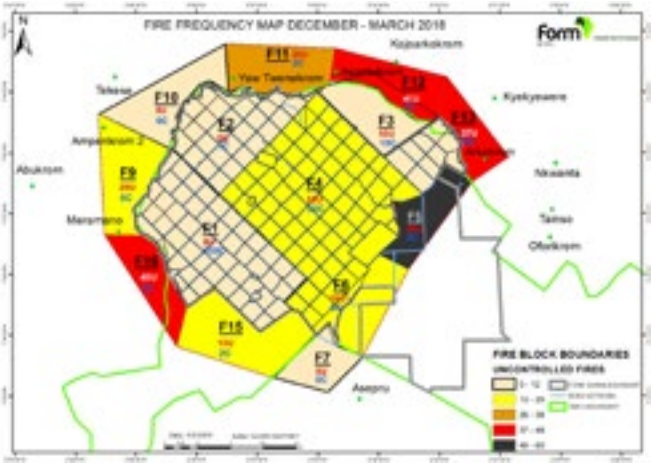
Community fire management plans aim to prevent fire outbreaks and limit their spread if a fire gets out of hand. Based on these plans, squads and farmers take

planned preventative measures. These include creating and clearing strategically located firebreaks to protect farms and villages, and widening roads so that they can also serve as firebreaks. In some cases community fire squads join forces to carry out well-managed burns early in the dry season in unmanaged areas around the forest reserve, or to prepare large defensive firebreaks to protect several villages.

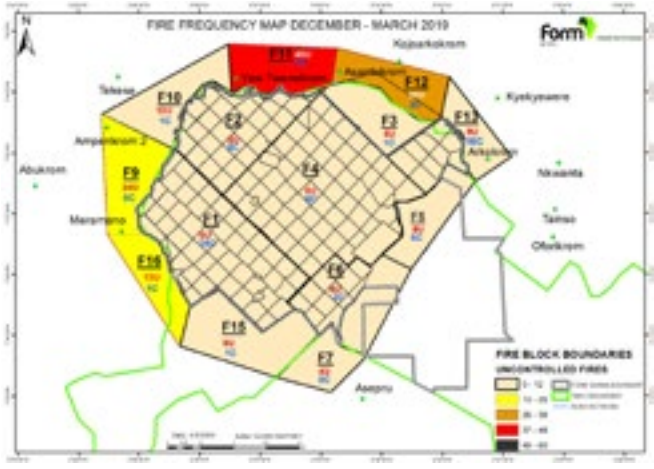
Impressive results

In 2021, after four years of implementing the community fire management project, the area under community fire management covered 6,150 hectares (ha), which helps to protect the 8,072-ha forest reserve. The number of wildfires in the total area was reduced by 78% compared to 2018 (Figure 1).

Communities have taken back control of the use of fire, with renewed skills and strengthened organization. This gives the 3,000 smallholders who farm in the programme area new confidence, as well as new economic opportunities from agroforestry. With less risk of fire, many farmers have planted cashew and mango trees in and around their fields that will provide valuable additional income in a few years, and are already having positive changes on the landscape. There is also a major positive environmental effect on the forest reserve, because the buffer zone around it is now permanently managed. Compared to using periodic fallows after annual crop cultivation, as was previously practised, farmers now see that it is worth the effort to protect their farms during the dry season.

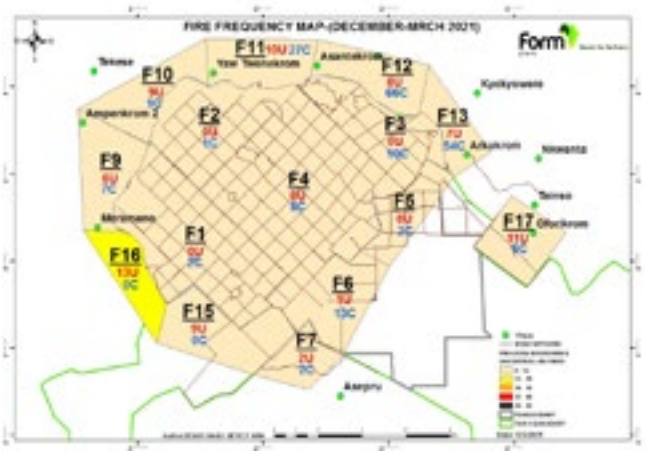


Map 1. Initial situation in 2018: 276 uncontrolled fires on community land around the Tain II Forest Reserve (green line represents the boundaries of the reserve).



Map 2. Situation in 2019: after one year with four operational community fire squads, the number of uncontrolled fire outbreaks was reduced by 78% compared to 2018 over an area of 2,647 hectares.

Map 3. Situation in 2020: after two years, with six operational community fire squads active on 4,845 hectares.



Map 4. Situation in 2021: after three years, with nine operational community fire squads active on 6,150 hectares.

Figure 1. The reduction in the number of wildfires in and around the Tain II Forest Reserve between 2018 and 2021. Darker colours indicate more uncontrolled dry season fires.

An equipped fire squad, ready for action. Photo: Melle Meivogel

These changes were summed up by Kwasi Asare, a farmer from Kotaa: "In the past, farmers of Kotaa used to plant cocoa trees underneath the large forest trees, but this changed over the past 20 years. I also stopped planting cocoa and grew maize instead because I did not want to risk that the trees get burnt during the dry season. But I dare to plant fruit trees again. Because of the fire squad of my village I do not need to worry, I can count on their assistance, and around our village there are far fewer uncontrolled fires than before. I now realize that when my neighbour's farm burns, mine is in danger too, and we can only have flourishing farms when we work together."

Form Ghana also sees the impacts of developing and implementing robust company fire management in its timber plantations, and how these impacts are complemented by the community efforts. The strong and trusting relationship that the company built with the neighbours over the years has been further strengthened, helping it to become even more embedded in the landscape. Form International is taking this approach to other landscape restoration programmes in Peru, Indonesia and elsewhere in Ghana. The approach developed here will be adapted to fit the local context and existing structures of these new areas.

Vast unmanaged areas of bushland, dominated by elephant grass, have been turned into diverse, productive and healthy farms with increased tree cover and perennial crops. Farmers in these areas say that it is now feasible to protect their farms from fire. The well-functioning community system makes possible what in the past was not worth the risk. In fire-prone areas, community fire management provides a critical basis for joint landscape restoration initiatives that wish to stimulate tree planting, environmental conservation and development of agroforestry.

The most significant impact has been that local people took back responsibility and control over wildfires, which were their common enemy. Prior to the programme, community fire volunteers felt powerless. They are now proud and confident, since they are part of the solution to protect the lives and livelihoods of their neighbours. People now know that they are capable of making a large impact on a large scale.

Upscaling potential

The programme's approach would likely lead to similar achievements if it were implemented in other communities and regions where forest and farming communities also suffer from annual wildfires. The key element for success is a community-based approach that focuses on fire prevention rather than suppression. The process has to begin with open and transparent discussions so that participants fully understand the challenges at the governmental, social, environmental and organizational levels. It must emphasize engagement, collaboration and unity between various groups, especially when revising bylaws, operating procedures and organizational structures. Any newly introduced techniques should complement traditional

practices and not replace them, in the same way that privately led activities should complement and not replace government programmes and initiatives.

In this case, the initiator of the programme was a private company that implemented activities alongside communities, traditional authorities, leaders and government institutions, including three regional departments of the Ghana National Fire Service. However, further scaling out this approach will require lobbying at the national policy level in order for the fire services to be allocated increased resources, and to support them to distribute these resources to their regional departments. In the meantime, other private companies could start by adapting and adopting this community fire management approach to protect their investments, with the full collaboration of the fire service, communities and traditional authorities.

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4.2

Cultivated land is resistant to fire due to the presence of moisture and a lack of dry fuel, and can act as a fuelbreak. Photo: Harifidy Ratsimba

Agricultural fuelbreaks in sustainable fire-resilient landscapes in Madagascar

Harifidy Rakoto Ratsimba, Joary Niaina Andriamiharimanana, Michaela Braun, and Johann Georg Goldammer.

"Establishing agricultural fuelbreaks helps to create fire-resistant mosaic landscapes, including new farmland, while reducing forest degradation and deforestation."

Introduction

The use of fire has been part of agricultural and forestry practices for millennia and is still practised today throughout the tropics, including Madagascar. However, uncontrolled fire is also one of the main threats to natural habitats, ecosystems and species in Madagascar, being especially damaging in with rich biodiversity, such as protected areas. Fire has affected much of the country's unique biodiversity, characterized by substantial endemism of more than 80% in plants, 90% in reptiles and mammals, and 99% in amphibians. The high frequency of fire in Madagascar has also increasingly shaped landscapes, gradually degrading closed forest into savanna and grassland. Landscapes are affected by the cumulative effects of fire and other human activities, particularly logging, charcoal making and the planting of exotic trees in reforestation projects.

Active fire response is complicated by a lack of equipment and capacities; this fire is burning in the southern part of Ankarafantsika National Park. Photo: Harifidy Rakoto Ratsimba

The main cause of uncontrolled fires in forested areas is the clearing of land for slash-and-burn farming, often carried out by poor farmers with extremely limited resources. To a lesser extent, wildfires spread from agricultural fields and pastures to wetlands, where fire is used for conversion into rice fields.

Context

The impacts of uncontrolled fires have long been known. In 1881, Queen Ranavalona II published the 305 Articles code, which included a formal framework for forest management and specified sanctions for offenders (Julien 1932). Article 101, for example, stated that "Forests must not be burnt; those who burn them will be put in irons for 10 years." Before independence in 1960, more than 40 laws or degrees were enacted that prohibited fires for forest clearing, and regulated crop and pasture fires, with penalties of five to ten years' imprisonment, and obligations to fight fires at the local level (Rasamoelina 2003). At that time, at least 2,500,000 hectares of fires per year were reported (Gendarme 1960).

Large areas continued to burn each year: 1-3 million hectares (ha) annually between 1970 and 1984. A drastic improvement began in the 1980s, with the development of initiatives by the national government, financial instruments, and through the awareness and empowerment of actors and citizens. This reduced the annual burned areas to 0.1–1.0 million ha between 1985 and 2000 (Rasamoelina 2003). However, this work was hampered by a lack of local interest in fighting fires, and by the absence of suitable equipment and capacities and of dedicated fire services.

In recent years, the extent of burned areas has risen sharply, with more than 5 million ha burned annually on average between 2017 and 2021, as reported by the Regional Eastern Africa Fire Monitoring Resource Center. This increase, however, may be due in part to improved technologies that allow for very accurate evaluation of burned areas through high-resolution satellite images.

The development context

In Madagascar, agricultural extensification continues to be promoted by agricultural policy, which allocates fertile land — often in lowland wetlands and natural forests — for conversion into farmland. This is accompanied by the use of fire for clearing and shifting cultivation and for renewing pastures, largely by smallholders with limited access to agricultural inputs, labour and equipment, and decreasing plot sizes with very small family farm holdings averaging 0.87 ha per household (MAEP 2007).

To address this, the government, with the support of technical and financial partners, has implemented various approaches that focus on specific sectors, such as water management, biodiversity conservation, land restoration and agricultural development. These approaches have increasingly been combined to promote multifunctional landscapes that are adapted to the needs of a range of stakeholders.

An evolution in approaches

Landscape approaches go back decades, but tended in the past to focus on environmental objectives through conservation of large forest holdings or watersheds, and through reforestation, often using exotic species. In 1946, soil scientists first undertook an analysis of Malagasy soil types. This involved an assessment of different types of erosion and possible means of control, noting the importance of soil organic matter and the role of trees (Segalen 1948). Since then, the dominant discourses in both scientific approaches and operational responses have been geared to reforestation, especially on steeply sloping land.

Agricultural development efforts concentrated on mechanized ploughing practices on flat farmland and in large irrigated areas. Schemes in the 1950s focused on reforesting watersheds upstream of reservoirs and rice fields. This approach was later replaced by agroforestry, including coffee and other trees, and in the 1990s by the promotion of agrosilvopastoral systems (Chabalier 2005). However, these approaches, like previous ones, were based on the premise that technical solutions should replace traditional land-use systems, and this tended to lead to confrontations with smallholder farmers.

In the late 1980s, experts criticized the frequent failure of previous management approaches, especially those efforts that focused on erosion control. They proposed more participatory strategies that attempted to improve smallholder livelihoods while also enhancing soil fertility, water infiltration and cropping systems, fusing local and technical knowledge, and adapting to evolving ecological and economic conditions. However, promoting and adopting such practices was limited by the context of three- to five-year projects; successful adoption requires much more time. For example, it took 10 to 20 years for the positive impacts of the practice of off-season crops and rotations — introduced in the 1990s — to become apparent.

Forest landscape restoration

Early sustainable land management efforts were limited to practices that reduced runoff and erosion and increased soil fertility. Broader approaches emerged over time that included the management of water, biomass and soil fertility being extended from plot level to cover whole watersheds. However, improving agricultural production or farmer income was rarely a goal, and many programmes even sought to limit farming. Forest landscape restoration (FLR) is the latest incarnation of these broader approaches. It is more a process than a set of management actions, and it explicitly includes social and economic development at its core, aiming to improve agricultural production, biodiversity (of both crops and wild species), ecosystem conservation, and local livelihoods. Inclusive multi-stakeholder dialogue is also a crucial component.

Using the FLR approach, regional and communal land-use plans have been initiated in some areas of Madagascar, first appearing in the late 2000s for

Fire control seems to be impossible on forested land (left), while some fire management is carried out in agricultural areas (right). Photo: Harifidy Rakoto Ratsimba

Developed agricultural areas in valleys are rarely affected by large savanna fires. Photo: Harifidy Rakoto Ratsimba

implementation over a 15-year period. In theory, they included landscape dimensions, but in practice, they were constrained by a lack of effective decentralization of capacities and decision-making. In addition, the key actor of change in FLR is the farmer or landowner — a fact that was often neglected, if not ignored entirely. Also, concepts of land-use planning and land tenure have tended to be considered in different ways, whereas in FLR they should are addressed together to ensure a transition to more sustainable land use.

Lessons for developing fire-resilient landscapes

The evolution of approaches to land use in Madagascar includes examples of cumulative analysis and expanding expertise over more than 80 years to address the complex issues surrounding sustainable land management, especially in the face of fire. Several key findings have emerged.

- Cultivated farmland rarely burns, except when plots are cleared by fire (which creates a risk of the fire spreading if it is not controlled).
- Forest land has long been protected by firebreaks (see Box 1); these are usually 3–10 metres (m) wide, depending on resource availability (mainly labour). However, firebreaks are costly to maintain, due to the regrowth of vegetation, which has to be removed at least every three years.
- Savanna and grassland areas are considered wasteland by farmers (Carver 2020), who see value only in cultivable areas, and think that forest land is useful only for harvesting tree products, or to be cleared for farmland (Goldammer 1988). These areas, now considered as degraded land, today represent almost two-thirds of the country.
- Restoration efforts, which are necessarily long term, have been hindered by issues regarding unclear land ownership.
- The need to improve smallholder livelihoods has received inadequate attention, even though farming is the main source of sustenance and income for more than 80% of the country's population.
- Natural ecosystems have their own inherent capability to regenerate, but human activities weaken this ability, which means that a deeper understanding is needed of appropriate nature-based solutions.

Agricultural fuelbreaks – a response to multiple issues

'Classical' firebreaks are usually 3–10 m wide. They limit the impact of fires, but require clearing every three years (see Box 1). They also have little influence on fires that are started within forests for slash-and-burn cultivation; this is a survival strategy for the poorest rural people, who need land to produce food.

From these observations was born the idea to create broader agricultural fuelbreaks, 25–100 m wide (see Box 1). They can be created by farmers and can generate

additional livelihood options while also limiting the build-up of biomass or fuel load through regular cultivation.

Box 1. Definitions

Firebreaks – "Any natural or constructed discontinuity in a fuelbed utilized to segregate, stop, and control the spread of fire or to provide a control line from which to suppress a fire; characterized by complete lack of combustibles down to mineral soil (as distinguished from fuelbreak)."

Fuelbreaks – "Generally wide (20–300 meters) strips of land on which either less flammable native vegetation is maintained and integrated into fire management planning, or vegetation has been permanently modified so that fires burning into them can be more readily controlled (as distinguished from firebreak). In some countries fuelbreaks are integrated elements of agro-silvopastoral systems in which the vegetative cover is intensively treated by crop cultivation or grazing."

Source: FAO 2013

Agricultural fuelbreaks have multiple aims, which include integrating systems that limit the frequency and spread of uncontrolled wildfires, reversing the conversion of forest to farmland or to otherwise becoming degraded, increasing the ability of ecosystems to regenerate, and balancing the needs of communities to produce their own food and protect ecosystem services. See Figure 1.

Establishing agricultural fuelbreaks requires substantial investments in the first year, but they do not then require any follow-up costs for clearance. The land must be ploughed to break up compacted soils, and amendments must be added to ensure enough fertility to grow crops, which happens during the rainy season. Biomass is eliminated before the dry season.

Most importantly, land-use rights need to be secure to ensure that farmers are willing to invest their own resources over the long term in the plots allocated to them, while also respecting local, sub-national and national rules. This security gives value to the degraded land within fuelbreaks. Plots have to be large enough to attract farmers, however; soil fertility is generally very low, and farmers require some production from the first year to support household food security. Thus, agricultural practices must respond to the technical issues of fertility (use of inputs, crop associations, etc.), economic issues related to subsistence, and social issues related to land ownership.

Successful implementation

The first 65 km of agricultural fuelbreaks in the country were established in Boeny Region (mainly around Ankarafantsika National Park) in northwestern

Territorial organization remains a major issue in landscape management, with underlying social and technical challenges. Photo: Harifidy Rakoto Ratsimba

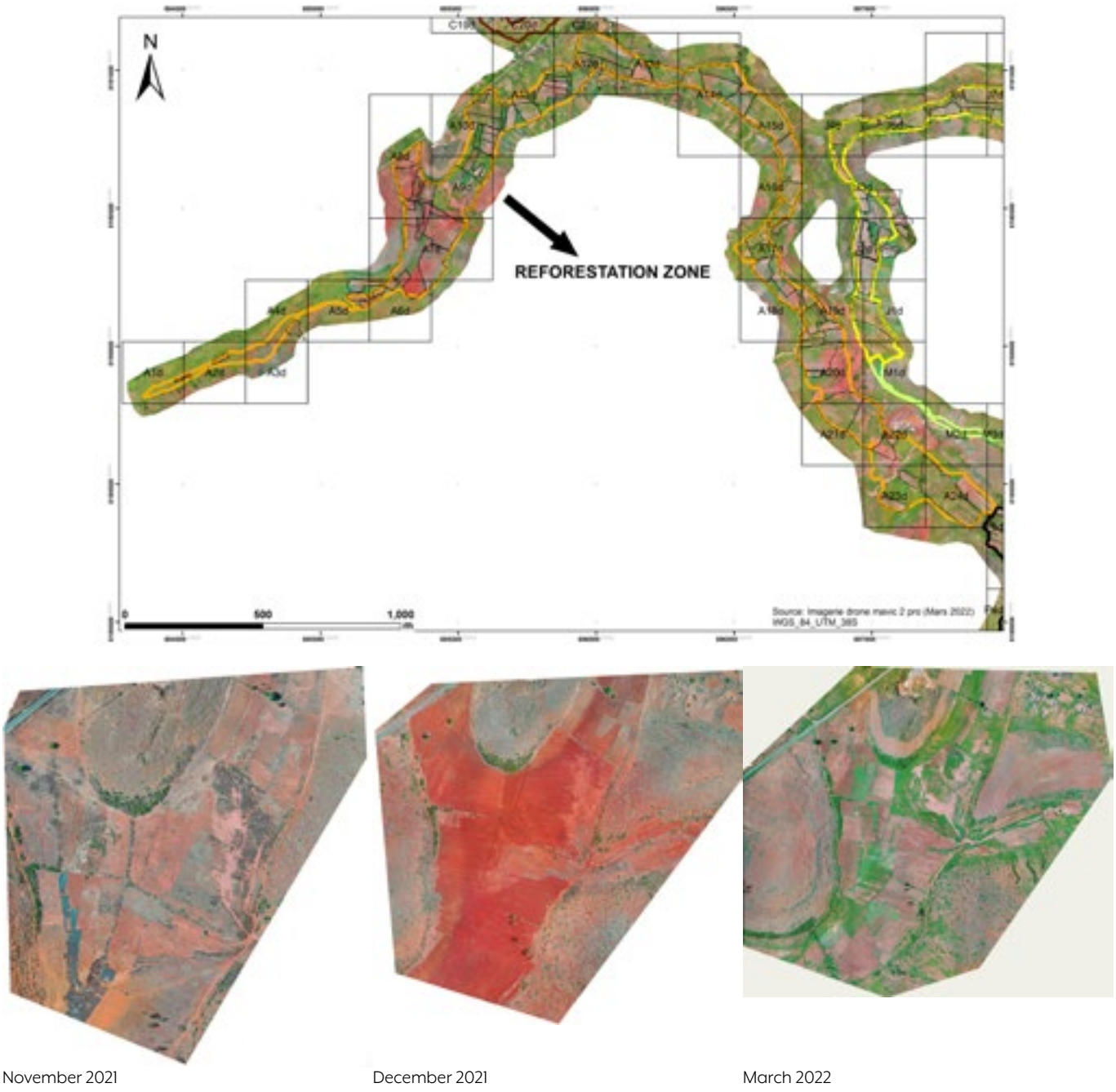

Figure 1: Visualization of the results of setting up fuelbreaks around a reforestation area. Source: Harifidy Rakoto Ratsimba

Madagascar between 2021 and 2022. This effort was supported by the GIZ PAGE2 project (*Programme de Protection et Exploitation Durable des Ressources Naturelles à Madagascar*), the Land, Landscape and Development Research Lab, and the Regional Eastern Africa Fire Monitoring Resource Center.

Established in generally open landscapes dominated by grassy savanna, these fuelbreaks limit the spread of fires, which occur with varying frequency. They also create an additional 615 ha of farmland for crop production; this should help to limit further slash-and-burn activities in the national park and so further reduce the potential for future fire ignitions.

Due to the benefits seen by local smallholders and decision makers, the use of such fuelbreaks has now spread to more locations far from the national park, creating more new farmland and further reducing the risk of uncontrolled wildfires spreading. In 2022, an additional 400 ha of agricultural fuelbreaks are planned; and are envisaged around other protected areas in the coming years.

The keys to success are territorial land-use plans that make it possible to create fire-resistant mosaic landscapes that combine forest and agricultural land. A priority of territorial planning is to reduce the impact of fires for multiple reasons, such as the protection of wooded areas and biodiversity zones and the protection of nearby residential areas. The goal is to find sustainable solutions to the problem of fire, while in parallel, creating agricultural, economic and social opportunities.

The next stage is to plant wide spaced trees in the fuelbreaks to reduce erosion and improve nutrient cycling and availability, while diversifying production (for example, a lemon and moringa plantation has already been established in the sloped area of Boeny Region). Agricultural fuelbreaks should eventually resemble agroforestry plots, and their elongated structure should gradually give way to an integrated landscape with multiple functions (Figure 2).

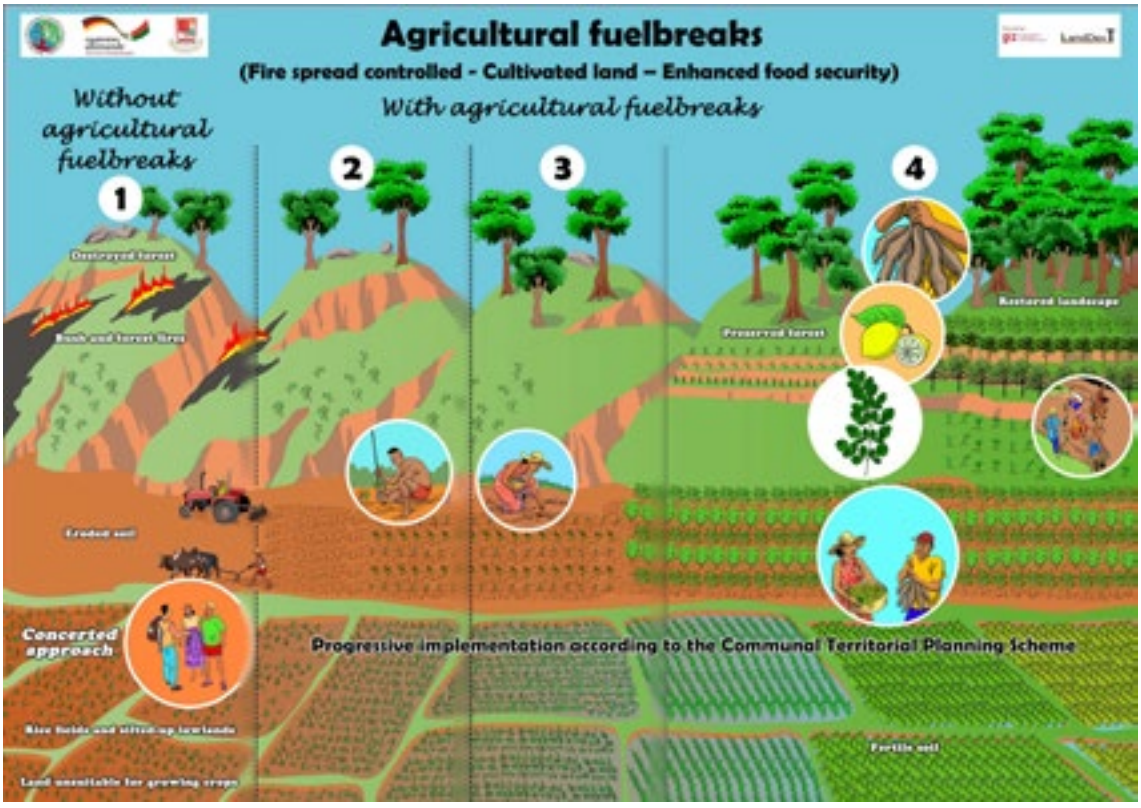

Figure 2: Agricultural fuelbreaks as a component of integrated and multiple-use landscapes. Source: LLandDev.org

Conclusions

Land tenure remains a key challenge in establishing agricultural fuelbreaks. Indeed, land ownership remains the key driver of farmers' interest in sustainable land management. Combining short- and long-term investments is vital, particularly in the process of maintaining and restoring fertility. Farmers are always interested in multiple benefits over a range of time periods (with a strong bias towards the short term).

The process of establishing fuelbreaks is relatively cumbersome. It requires the support of decentralized services (responsible for territorial land-use planning) and centralized services (for technical support, particularly in the agriculture, livestock, forestry and land sectors). This makes scaling up difficult in Madagascar, where sectoral ministries are understaffed as a result of structural adjustment policies in the 1990s. This problem cannot be addressed by projects that have neither the mandate nor the timeframe for this type of support. Two key elements are thus becoming apparent as framework conditions for long-term success: capacity strengthening at the community level, and finding ways to connect directly with farmers for a continuous exchange of information based on a common learning model.

The concept of agricultural fuelbreaks is not new. It draws on experience with and knowledge of sustainable land management in Madagascar developed over the past century. It also fits into mosaic management and landscape approaches that date back several decades.

However, the concept has been, and still is, challenged by contrary aspirations to manage large uniform areas in a way that facilitates operational management but weakens fire response capability, particularly in forests. The current difficulty in controlling large fires illustrates the shortcomings of that approach, and agricultural fuelbreaks appear to offer a sustainable approach to achieving fire-resilient landscapes.

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4.3

Edges of gallery forests and forest islands are sometimes scorched by high-intensity fires in the late dry season, which park managers seek to avoid by implementing early-season burns. Photo: G. Rücker

A strategic approach to sourcing and using fire information in northern Côte d'Ivoire

Gernot Rücker, Amara Ouattara, N'Dri Pascal Kouame, David Leimbach, Dejan Popovic, Jean-Luc Kouassi, Djafarou Tiomoko, Roger Kouadio, and Adama Tondossama.

"A new web and mobile app has helped to establish improved decision-making processes in fire management that are characterized by continuous learning and development."

Introduction

Fire management in African savannas, including those in Côte d'Ivoire, is a complex and interdisciplinary task. It needs to consider interactions among many factors, such as management interventions by a range of actors and long-term transformations to the regional climate. Changes in fire regimes alter the dynamics that favour either forest/woodland or grass-dominated landscapes, and thus can have substantial implications on carbon storage, greenhouse gases (GHGs) and particle emissions, habitats, biodiversity and human livelihoods. Fire regimes also influence the availability and spatial distribution of grass species, which provide forage for wildlife and livestock.

In many protected areas across Africa, information on fire regimes and land management has not been available at the required level of detail. Furthermore, it is challenging to compile information in a way that is useful for decision making and for tracking the effects of implementation. On the

Comoé National Park is one of the largest in West Africa, with exceptional biodiversity. Photo: G. Rücker

other hand, recent years have seen a rapid increase in free Earth observation data, computing power, network speed and web-based geospatial visualization and analysis technologies.

This article describes a successful attempt to compile baseline information on fire regimes in Comoé National Park, Côte d'Ivoire, at different spatial and temporal scales. Data are made available through a system that supports fire management planning, reporting, and documentation and analysis, and that is used to implement management activities.

Comoé National Park

Comoé National Park is situated between the Sudanian savanna and Guinean forest formations in northeastern Côte d'Ivoire. Covering 1,148,756 hectares (ha), it is one of the largest protected areas in West Africa. The area first received some protection in 1926, was enlarged and declared a national park in 1968, and became a UNESCO World Heritage site in 1983. In 2002, during political and military crisis and unrest, park management team was forced to abandon the region and the park, leading to an increase in poaching, uncontrolled fires and other human-induced degradation. After the crisis, the Ivoirian Office of Parks and Reserves (Office Ivoirien des Parcs et Réserves, OIPR) was created and took over the management of the threaten park with support from its partners, and in 2017 the park was removed from the list of World Heritage in Danger; it was put on the list in 2003.

Comoé National Park hosts one of the most biodiverse savannas in the world. The park is home to 135 different mammals, including 11 species of primates, among them critically endangered West African chimpanzees (Lapuente et al. 2020). Within its large open and grass-dominated areas, rainforest islands exist in the south, with gallery forests along rivers; wooded savannas dominate in the east (Goetze et al. 2006).

Park boundaries are visible on dry-season satellite images (Figure 1), with dark grey to black areas (indicating burned areas) dominating inside the park, except for green forest islands and gallery forests. Outside the park, green and brown colours indicate mango and cashew plantations, agricultural fields, villages and other areas that are protected from fires. Where population density is high and cash crops dominate, large burned areas are uncommon; fuels are not continuously available, so fires will go out or be suppressed. Large burned areas are confined to protected areas.

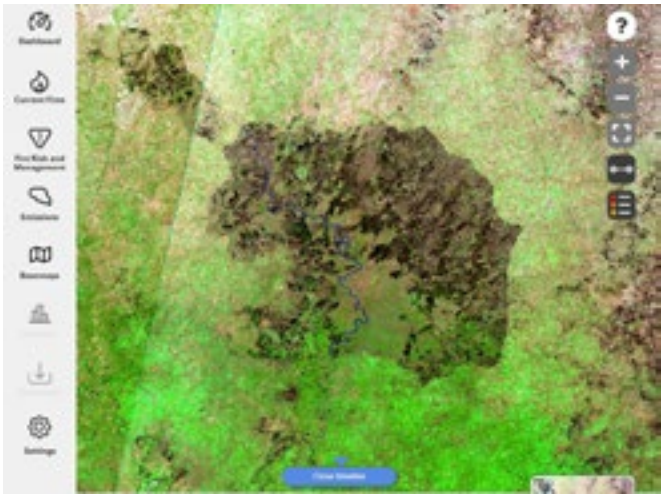

Figure 1: During the dry season, large parts of the park burn annually and park boundaries are easily identified, as shown here on a false-colour Sentinel-2 satellite image (December 2019). Source: ZEBRIS. Data: ESA

Fire management

Many people consider fire a threat, and see charred, black-grey landscape as negative. However, people in savannas see fire as being closely linked with their livelihoods, and use it as a tool for various purposes. This article presents some of the basic questions about and ways to achieve a fire-smart landscape.

Colonial rule introduced fire-exclusion policies in many countries, including Côte d'Ivoire. This often had disastrous results, since accumulated fuel led to catastrophic late-season fires (Laris and Wardell 2006). In later years, conservation area managers and policy makers sometimes tried to exclude people from certain areas and restore a pre-human "natural" state. In Kruger National Park in South Africa, for example, between 1992 and 2002 park managers decided to allow only lightning-caused fires to spread, while suppressing human-caused fires. The suppression of these fires led to fuel accumulation and massive fires. Park managers therefore changed their approach and recognized that, even in conservation areas, people are part of the landscape and are one of the elements that define the fire regime (van Wilgen et al. 2014). See Box 1.

An information-driven fire management strategy

Although fire is an integral part of ecosystems in Comoé National Park, uncontrolled high-intensity fires are considered a threat to habitats and wildlife. In 2016, the protected areas authority (OIPR) began to develop a fire management strategy. Implementation was supported by monitoring fire activity, including a baseline analysis, assessing current fires and monitoring management activities. That same year, after a period of evaluation, OIPR decided to use an online information platform that was then available as an early release (Zebris 2022).

All data were made available through the online platform for browsing in web-GIS and for download (see Figures 1, 2, 3 and 4). Over the years, the platform evolved from a monitoring and information entity to a decision support tool and management information system to track and assess the impact of fire management approaches. Detailed data accumulated over several years now help to shape the progress of the park's fire management strategy. The strategy balances conservation objectives — such as maintaining fire-dependent ecosystems and opening up encroached grasslands with high-intensity fires — with avoiding large fires and reducing fire intensity in sensitive sites. A parallel aim is to reduce greenhouse gas emissions and smoke pollution, and to maintain or increase carbon stocks in selected areas.

Box 1. Fire management in savannas

Reducing greenhouse gas and particulate emissions from savanna fires has gained traction as a means of mitigating climate change. Some people suggest that implementing indigenous practices such as low-intensity, early-season burning could generate carbon credits by reducing emissions, while also supporting conservation (Lipsett-Moore et al. 2018). Other, however, say that re-establishing indigenous fire management is flawed, as it is already practised and there is little room for improvement. Instead of changing savanna fire management in West Africa and compensating local communities for that change, it has been proposed that local people should be rewarded for maintaining their traditional fire management approach, which includes both early-season burning and the widespread use of low-intensity back fires (Laris 2021). In northern Australia, for example, recognizing that colonial-era fire suppression only resulted in more and larger fires, the West Arnhem Land Fire Abatement (WALFA) project revived indigenous burning to create a landscape dominated by early-season fires and patchy burns (Russell-Smith et al. 2013). This approach is now being scaled up.

To make things more complicated, in many parts of Africa the encroachment of trees and shrubs in savannas is perceived as a threat to biodiversity conservation and livelihoods, and the use of high-intensity or high-frequency fires has been promoted as a means to reduce unwanted woody cover and keep grasslands open. Managers of protected areas sometimes have to balance competing fire management objectives, such as using fire to maintain or expand iconic savanna landscapes and their characteristic species, while also reducing GHG emissions and increasing carbon stocks by shifting fire seasonality and reducing fire intensity (Archibald 2016). Hence, spatially explicit planning and monitoring is important for fire management decision making, implementation, and evaluation.

Figure 2: Colours indicate the month when burns were detected. Source: ZEBRIS

Figure 3: Map of potential landscape vulnerability to fire, to guide management decisions. Source: ZEBRIS. Data: OIPR, ZEBRIS

Monitoring

The OIPR initial objective was to establish a baseline of fire activity in the park. The first monitoring products provided information about burned areas and fire emissions. Burned areas were analyzed based on freely available data, initially from Landsat and Sentinel-2 satellite data. After the launch of a second Sentinel-2 satellite in 2017, satellite images at 10-m spatial resolution became available every five days, and starting with the 2017/18 fire season only these images were used for monitoring.

The size of burned areas in the park varied between 700,000 hectares in 2016/17 to almost 900,000 hectares in 2019/20. This means that between 60% and almost 80% of the park burned annually. The landcover types affected are similar from year to year: most (80%) of the burned areas are shrub savannas, followed by woody savannas (10%). Most burning occurs in December, but substantial fires can also occur in January and February.

GHG emissions were estimated based on the heat signal (or 'fire radiative power' of actively burning fires) observed by satellite; this correlates to the rate of biomass burning (Wooster et al. 2005). The continuous observation of a fire enables a calculation of the amount of biomass burned. Since data from the sensor that measures heat signals are available only up to four times daily, a statistical model is used to interpolate between observations. Based on this methodology, GHG emissions were estimated to be 883,000 tCO2e per fire season.

Analysis and implementation

Once initial baseline information on fires was available, and an analysis of vulnerability was carried out, it was possible to establish priorities for management activities. Within the strategy developed by OIPR, management fires are an important element to control fuel load and reduce unwanted tree encroachment in selected areas, where pioneer species such as African birch (*Anogeissus leiocarpus*) establish and start to shift boundary areas from savannas to forests (Hennenberg et al. 2005).

To better understand vulnerability, managers needed more information on the components of fire activity and fire regimes in various areas of the park. They used a fire behaviour prediction model to calculate potential fire

Checking on a burned area using the mobile phone app. Photo: G. Rücker

intensity. That intensity is derived from weather, terrain and land cover and is now routinely calculated daily during the fire season.

Managers then analyzed vulnerability, based on this modelled fire intensity and on landcover type. They planned fire management activities according to four zones of vulnerability.

1. Zones where fires should be excluded (gallery forests, forest islands).
2. Zones where early-season burning should be used to reduce fuel accumulation (tree savannas, forest fringes).
3. Zones where high-intensity burns should be used to combat tree or bush encroachment into areas dominated by grassland (or in limited areas in bush savannas).
4. Zones with no specific vulnerability and thus no specific fire management objective.

In the 2018/19 fire season, managers implemented and documented controlled fires for the first time, mostly along the eastern borders of the park in order to protect neighbouring villages. By comparing satellite images, managers could see that controlled fires covered an estimated 6% of the total burned area. To determine if the controlled fires had burned at the desired intensity, models were developed for the day and time of burning; these showed that controlled fires burned at moderate and sometimes moderate-to high-intensity.

New tools

Soon after the introduction of management fires, a web-based tool was developed for planning and

Figure 4: Management fires as documented by firemaps.net. Fire fronts are orange/red; burned areas are black; live vegetation is green; and dry vegetation is brown. Source: ZEBRIS. Data: ESA, OIPR

Experimental burns helped to corroborate information derived from models and satellite data. Photo: G. Rücker

documenting them. It was complemented in 2022 by a mobile app that enables field teams to have online access to key information, and allows fire management activities to be viewed, developed and revised. This supports improved coordination between field teams and office staff. Management fires can thus be planned in the office or in the field and information about them can then be shared. The tool also supports an administrative workflow so that managers can chart the progress of fire management activities. The forecast mode of potential fire-intensity maps (a four-day forecast is currently implemented) enables planning of management burns depending on likely weather conditions. A management dashboard contains information on actively burning fires and calculates current GHG emissions in near real-time. Information on weather conditions that affect fire occurrence and spread is available from daily weather forecasts. Managers update maps of burned area monthly, based on the most recent satellite images.

Experimental burns

Managers conducted four experimental burns in 2019 and 2022 in the late dry season. The goal was to link maps and model data with ground-based information in order to validate predictions of fuel consumption, emissions and fire intensity . They sampled fuel load and combustion completeness and measured fire radiative power in order to evaluate the relationship between heat release and fuel consumption used in the satellite-driven model. These experimental burns indicated that modelled fuel consumption was realistic, but may be underestimated, as long-term average satellite data from nearby areas were about 30% lower. Information on fire intensity obtained from two of the experimental burns also showed that the satellite model provided realistic results but may overestimate fire intensity. Further experimental burns will follow to characterize GHG emissions.

Towards improved fire-smart management

Adopting these web tools was characterized by continuous learning and development and helped OIPR to establish new decision-making processes in fire management. The platform served first as a monitoring and information device, then as an instrument to develop a fire management strategy, and finally, as a way to plan, document and monitor the implementation of the authority's strategy. Managers have compiled important information on the fire regime in the park and have laid the foundations of a science-based and accountable fire management strategy.

Based on the findings so far, the next steps will be to make more in-depth assessments of fire management options through improved vulnerability and management maps. This will require more research on fire intensity. That is a key variable and is not easy to observe over large areas, but using new methods now being developed will help with this. In addition, the impacts of climate change on the park's fire regime will also be investigated.

Further analysis will also be undertaken to gain a deeper understanding of why fires are started by local people in the park and how these fires are connected to their livelihoods. Dialogue with local stakeholders and further science-based assessment will help to pinpoint where changes in the fire regime could lead to an enhancement of biodiversity and a reduction in emissions of fire-related GHGs and pollutants. Overall, the development and application of this web-based tool has shown clear benefits to fire management in Comoé National Park, and merits piloting in other protected areas in the region.

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Assessing wildfires from the air, in the Bale Mountains. Photo: GFMC

4.4

Fire management in Ethiopia: past, present and future

John Livingstone, Habtemariam Kassa, Kebede Yimam, Niguse Hagazi, Amsale Shibeshi, and Solomon Zewdie

"A national fire management strategy is required, inclusively developed across sectors and with multi-stakeholder support."

Introduction

In Ethiopia, wildfire has played a fundamental role in the evolution of dryland ecological systems, and fire is a common element in the ecology of rangelands, savannas, shrubland, woodlands and dry forests. The frequency and impacts of wildfires have increased in recent decades, however, especially in the western and southwestern woodlands and national parks, due to increased human activities (Johansson et al. 2019). Prohibiting the use of fire in the rangelands of southern Ethiopia since the 1980s is blamed for allowing bush to encroach into grasslands, with severe effects on biodiversity and pastoral livelihoods (FfE 2009).

The 2018 *National Forest Law* states that forest developers and users must protect forests from fires and must report fire occurrence at once to responsible bodies; the law can impose sentences of 1 to 10 years for setting fires in forests (FDRE 2018). However, the law does not specify

Burned land after a wildfire in the Bale Mountains, Ethiopia. Photo: GFMC

the role of federal and regional governments in fire management, beyond enforcement. There is no national fire management strategy or policy.

This article reviews the history, causes and impacts of wildfires in Ethiopia, identifies gaps, and discusses plans for improving fire management using an integrated approach at national, subnational and community levels.

History of fire use and wildfire

Centuries ago, warring parties set fires in Ethiopia's high forests to chase out their enemies (Lemessa and Perault 2001), and feudal lords cleared forests on mountaintops to establish settlements from which they could observe enemies in the distance (Teketay 2001). There is a long history of using fire to clear forests to establish new settlements and open up new farming land.

Climate change — with more frequent and severe drought — is an important factor in the increase in the number and intensity of wildfires. In 1984, wildfires affected more than 300,000 ha in Ethiopia; two-thirds of them were in high forests (Lemessa and Perault 2001). During the 2000 drought many large fires damaged more than 150,000 ha of forests (FfE 2009) and forced the country to call for international assistance (Bekele and Mengesha 2001). The fires of 2000 greatly affected Awash and Nechsar national parks, Borana woodlands and the grasslands of pastoral areas, eastern Ethiopia and the Bale Mountains (FfE 2009). There were also major wildfires in the Bale mountains in 2007 and 2008, and in Yayu Biosphere Reserve in 2013.

Human pressure and intensified drought have seen Ethiopia recurrently affected by severe wildfire emergencies since 2019. Severe wildfires have affected most ecosystems, including humid forests and protected areas and sites receiving international funding, including under the REDD+ programme. In 2019, major wildfires in Simien National Park, a UNESCO World Heritage Site, took more than a month to be effectively controlled and then only after international support was obtained. Wof Washa forest was severely affected in 2021, when 14,688 ha were burned (EFCCC 2021).

Wildfires are common in the western lowlands, which are dominated by woodland, bamboo and grassland. These fire-adapted ecological systems are characterized and shaped by frequent natural and anthropogenic fires. Grasslands are especially prone to fire between March and May. People clear large areas for commercial farms, and burn crop residues rather than using them as fodder; these fires sometimes spread into woodlands. Trans-boundary fires cross to and from Sudan and South Sudan. Wildfires also occur in the forests of southern Ethiopia, which have little previous fire history.

Wildfire causes

Most wildfires spread from fires started by people, accidently in and around parks, and intentionally during the dry season by farmers and pastoralists (Teketay

2000; Lemessa and Perault 2001; FfE 2009; Johansson et al. 2019). Fire is used to clear rangelands of unpalatable dry grasses, invasive bushes and parasites that affect livestock, and to encourage the growth of fresh, palatable grasses for livestock grazing; to clear fields of crop residues and other unwanted vegetation during land preparation; and to clear forest and bushland for settlements and crop production or for tea or coffee plantations. Fire is also used to facilitate access; to drive away wild animals and rodents that damage crops, and snakes, parasites, toxic caterpillars and predators harmful to people and livestock; to harvest wild honey; and to clear the stumps of illegally cut trees, or during illegal charcoal making in woodland and dry forests. Fires set for these purposes frequently spread out of control. Agricultural burning, accidental fires and fire for traditional land management were reported as the cause of the loss of large forest areas in the Bale Mountains in 2000 and 2008 (Goldammer 2000; Belayneh et al. 2013).

Arson is another cause of wildfires. People set fires in national parks to demonstrate against park management. Each park has its own administration, with rangers responsible for routine management. The lack of negotiated benefit-sharing arrangements for park revenue leads to tension with surrounding communities, whose livelihoods have been undermined by the loss of access to water, pasture and trees within park boundaries. Fuel also builds up within parks. This means that fires in national parks, while perhaps less frequent, can be much more intense when they do occur, in spite of efforts to suppress outbreaks (Johansson et al. 2019).

Wildfires result from a complex set of social, political and economic circumstances. These are rooted in interrelated factors such as rural poverty, growing population pressure and low agricultural productivity (which drives smallholders to expand the area they farm), the absence of operational land-use policies, and weak capacity in forest tenure and law enforcement (Lemessa and Perault 2001).

Gaps in fire management capacity

Fires not only damage natural resources; they also undermine efforts to conserve natural forests and restore degraded landscapes through assisted natural regeneration, afforestation or reforestation. Recent wildfires highlight the gaps in Ethiopia's capacity to predict and control these fires. See Box 1.

Assessing fire profiles for countries, including Ethiopia (Goldammer and Mutch 2001), suggested that a system was needed for collecting meaningful fire data, and that wildfire reporting was hindered by limited capacity. The assessment concluded that the emphasis on emergency responses must be coupled with sustainable land-use policies and practices, and with effective inter-sectoral coordination, all of which help to reduce wildfire impacts.

Preliminary discussions between the authors and national government entities in 2022 involved the absence of a fire management plan and weak capacity for rapid responses to fire emergencies. After disastrous forest fires in 2000, a national roundtable conference was held by the Ministry of Agriculture with GTZ and GFMC, where a draft long-term fire management plan was discussed (Goldammer 2001). This was a serious attempt to develop an integrated forest fire management strategy that would establish measures for prevention and control, while accommodating the use of fire as a land management tool, and use remote sensing to provide early warning. However, no concrete steps were since taken beyond the drafting of a manual to control forest fires, which was not taken up effectively.

Box 1. Major gaps in fire management capacity

These gaps in capacity need to be addressed in order to develop effective fire management:

- incomplete understanding of the root causes of human-induced fires;
- limited data on trends in fire frequency and intensity, and high-risk areas;
- lack of a national forest fire management strategy that defines the mechanisms to prevent, detect, report and suppress fires;
- lack of a national land-use policy and plan;
- limited coordination between the forest law and laws in other sectors;
- few forest management plans, which are necessary to implement the revised National Forest Law;
- weak enforcement of existing laws;
- poor coordination and communication between various actors at various levels of government in and between regional states; and
- lack of firefighting equipment and trained firefighters, with a heavy reliance on international support and using local citizens and security personnel only for fire suppression.

To address these gaps and develop a national strategy, these actions are needed:

- identify and address the root causes of wildfires;
- gather data on fire risk and fire occurrence;
- update the map of high-risk areas;
- update the chronology of wildfire incidences;
- carry out efficient measures to prevent wildfire;
- establish and implement a mechanism to rapidly detect and suppress wildfires;
- build technological, financial, logistical and human capacity to forecast, detect, report and suppress forest fires and undertake post-fire rehabilitation measures;
- institutionalize mechanisms for networking, collaboration and coordination of actors at all levels;
- build on indigenous knowledge of wildfire prevention and management;
- ensure the participation of local administrations and communities in developing and implementing fire management plans; and
- allocate the required resources to develop and implement management plans.

The need for a national strategy

Not having a national wildfire management strategy continues to undermine Ethiopia's capacity for forecasting, preventing and suppressing wildfire. Fire management must be an integral part of land-use management policies and practices. These measures must consider cultural values and socioeconomic realities, as well as ecological differences in the areas where fires occur, including rangelands, dry forests and woodlands. In addition, multi-level governance is needed (EFCCC 2019). The devolution of responsibility and increased support for local decision-making are also important.

A national wildfire management strategy must be accompanied by an implementation plan, which must have the requisite financing. Potential financing mechanisms include establishing trust funds to support investments in measures such as constructing fuelbreaks, through revenues from taxes on charcoal and other forest products. Such investments could provide an opportunity to create employment for jobless and otherwise disadvantaged communities. Ethiopia lacks even basic capacity for fire suppression, and resorts to mobilizing soldiers, police and students when a major fire occurs. The country needs trained and properly equipped firefighters. Perhaps more importantly, there needs to be a paradigm shift towards accepting the need to live with fire where it is an inescapable part of local ecosystems and where its controlled use enhances rural livelihoods.

The national strategy must emphasize forecasting and prevention, early detection and swift action to suppress fire, using advances in science and technology, and identifying and addressing the challenges associated with scarce resources and uncoordinated institutional aspects. Fire management must also be integrated into the development of local livelihoods and in policy frameworks for sustainable land use. In addition, fire management must be seen in a broader policy context with respect to energy and Ethiopia's nationally determined contributions (NDCs). Carbon emissions from fires are not quantified or accounted for in the country. Since illegal charcoal production is another cause of fire, policy reforms in the energy sector could thus have positive effects on fire management.

Prohibiting traditional fire management in national parks and protected areas contributes to the expansion of tree cover and to carbon capture. This helps Ethiopia meet its NDC commitments, which depend heavily on forests and dryland restoration. But this approach also leads to a build-up of biomass that in the long term makes wildfires more likely and more intense, offsetting any shorter-term gains in carbon capture. Forests play a crucial role in climate change adaptation and mitigation: land use, land-use change and forestry (LULUCF) account for more than 80% of Ethiopia's mitigation contribution.

Following recent extreme wildfire events, there is a greater recognition and sense of urgency among policy makers, communities and development partners of the need to build capacity and to develop a well-informed fire management strategy. The national government is now taking steps to do this.

Towards improved fire management

Ethiopian Forestry Development (EFD), an autonomous federal body, is eager to address gaps in capacity and establish a coherent and effective fire management strategy. After forest fires in 2021, EFD took the lead in bringing together regional task teams to enhance the coordination of firefighting efforts. EFD worked with Italy's CIMA Foundation to develop a forest fire early-warning system using the myDEWETRA tool to collate and distribute remote sensing data in bulletins shared with regions (CIMA Foundation n.d.). This project, which ended in 2021, involved a capacity-building component. EFD has called for development partners to assist with new collaborative initiatives.

To support these efforts, the Pastoral and Environmental Network in the Horn of Africa (PENHA)-TBI and CIFOR-ICRAF have begun a joint programme, and federal- and state-level forestry agencies have expressed their desire to participate. The programme will include developing a draft national wildfire management strategy that relevant national authorities will ultimately implement. Implementation will contribute to high-level conservation impacts of reduced loss of forests and woodlands and minimized emissions from wildfires. The strategy and its action plan will help Ethiopia build capacity at the federal and regional levels to assess wildfire risk, share up-to-date information and undertake effective responses in fire detection, mitigation and control. The strategy will establish and make functional an inclusive fire management platform that brings together federal and regional government agencies, NGOs and community organizations. It will also build the capacity of actors engaged in implementing the strategy, with an emphasis on preventing, predicting, detecting, reporting and suppressing fires, while also integrating climate-smart practices in post-fire rehabilitation.

In summary, the programme aims to achieve five goals:

1. assess national forest management policies and fire management practices to identify opportunities and challenges;
2. map and prioritize high-risk areas where efforts and resources should be focused;
3. identify capacity gaps;
4. prepare a draft strategy to be considered by national authorities for assessing and acting on wildfire risk and making fire management part of forest and rangeland management decisions; and
5. facilitate experience-sharing between countries with improved capacity.

Conclusions

The PENHA-TBI/CIFOR-ICRAF programme will help fill gaps, but this alone will not meet the urgent need to improve fire management in Ethiopia and reduce the negative environmental, social and economic impacts of wildfires. Also needed is a concerted effort by government to promote participation, build awareness and understanding, change mindsets at community and policy levels, encourage cooperation between actors, and include development partners. This requires a sustained commitment over time.

Continuous capacity building is essential to address limitations at multiple levels, with the appropriate training and support. There is also a need for basic firefighting equipment, to reduce reliance on external assistance, and for establishing more efficient coordination with international partners for swifter and more effective responses. It is also extremely important to build task forces at the local level, and to train and equip them for rapid fire detection and suppression. These efforts should involve local administrations, communities and trained and equipped firefighters, and be supported by sufficient resources and coordination mechanisms.

Burned area in the Bale Mountains. Being able to collect data on areas burned is an essential component of fire management. Photo GFMC

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4.5

Wildfires are increasing in intensity and severity in Ghana. Photo: Joseph Asante

Inclusive fire management in Ghana's transitional zone

Joseph Asante, Mercy Owusu Ansah, and Daniel Kofi Abu

"Meeting long-term forest restoration goals requires prescribed and well-managed burns that pose minimal ecological and social risk."

Introduction

Fire use is integral to sustainable smallholder land use in much of sub-Saharan Africa, but poor fire management practices — coupled with hotter and drier weather conditions — have resulted in more wildfires. In addition, ever more conservation efforts and conversion of land are threatening the sustainability of biodiversity resources and livelihoods. Moreover, with population pressures and urban sprawl, more people are living and working in areas of high fire risk, thus increasing both the chance of wildfires occurring, and of local people suffering their consequences.

In Ghana, wildfires are now an annual occurrence (Appiah et al. 2010), resulting in the loss of lives, property and biodiversity. The annual loss of revenue from marketable timber due to wildfire is estimated at US$24 million (MLNR 2011). Similarly, wildfire damage to farms, agricultural produce and biodiversity resources remains extensive but unvalued, and little

A burned teak plantation in Atebubu-Amantin Municipal District. Photo: Joseph Asante

compensation is available. The Ministry of Land and Natural Resources estimated that by 2012 the annual total land area prone to forest fires would range from 30% in the high forest and transitional zones to more than 90% in the dry northern savannah zone (MLFM 2006). Increasing wildfires are blamed on the continued expansion of land conversion for farming using fire and on other livelihood pursuits, including hunting, charcoal production and cultural practices.

This article documents experiences and lessons from the Collaborative and Adaptative Community Fire Management initiative, implemented by Tropenbos Ghana under the project, Forest Landscape Restoration Through a Sustainable Wood Energy Value Chain. The approach was informed through local community consultations and a review of fire management policies and regulations, leading to support and incentives for safe and effective fire use and management. It is hoped that these findings can inform fire management practices elsewhere, while acknowledging that collaborative and adaptive community fire management is an evolving process and so requires constant learning to improve future practices.

The role of fire

Forest fires play crucial roles in maintaining forest ecosystems through recycling nutrients, promoting flowering and seed germination, and enhancing the sprouting of fresh browse. Fires can be beneficial in terms of reducing fuel loads and maintaining species composition and structure in fire-tolerant and fire-resistant ecosystems.

Wildfires, however, have been reported to cause forest degradation (Kosoe et al. 2015) and deforestation in Ghana (Danquah 2009). Forest fires also cause significant damage to timber resources, degrade soils and destroy biological resources. Increasingly frequent wildfires are burning large patches in dry forest areas that now suffer severe fires, but that were historically dominated by low-severity and moderate fires. This may be creating a shift to new states that will not sustain the same ecological and social functions.

Wildfires are modifying the structure and composition of natural forests in Ghana at rates that far exceed those of mechanical thinning and prescribed fire treatments (Reynolds et al. 2013). This demonstrates the threats that wildfire can pose to restoration efforts if it is not considered in a broad framework. Although the pace and scale of improved fire management have been increasing, wildfire continues to be the primary agent affecting vegetation across Ghana. This underscores the need to address the risks and effects of wildfires in planning for forest landscape restoration.

Fire trends and causes

Both 2014 and 2015 were record wildfire years in Ghana, across a wide range of natural and managed forest and other lands, and including large areas of high-severity burns. Wildfires also recurred in many areas that were receiving post-fire restoration efforts following previous burns. Ankasa Forest Reserve and neighbouring areas faced an increased occurrence of wildfires from 2015 to 2017 (Husseini et al. 2020). Since 2018, large parts of some major forest reserves — even in Ghana's high forest zone

— burned, including Abonyere and Bonsampepo, and the situation in the savanna zone also worsened. These major fire events presented a huge challenge to managers, stakeholder groups and communities in obtaining resources for restoring burned areas and protecting the rest of the landscape.

Various factors have been put forward as the cause of the alarming and increasing rates of deforestation in Ghana. Prominent among these in the northern savanna and transitional zones are land clearing for farming or new settlements, illegal logging for foreign exchange or local construction, and charcoal production, coupled with windstorms and prolonged drought. These factors are also interdependent.

Organizational issues that hamper wildfire prevention and suppression (Agyemang et al. 2015) include (i) poor institutional coordination and collaboration and unclear responsibilities; (ii) limited stakeholder involvement in wildfire discourse; (iii) limited understanding of wildfire trends; and (iv) the adoption of less effective and non-comprehensive approaches to fire management. However, farmers are also known to have knowledge that they use to manage wildfires that should be supported (Amissah 2009; Amissah et al. 2010).

National fire policies

Recognizing the need to address the effects of wildfires on forests and other ecosystems, the Ministry of Lands and Forestry developed the National Wildfire Policy in 2006. The policy promotes effective and efficient fire management for the sustainable use of natural resources and maintenance of the environment. Subsequent to this, fire management guidelines were drawn up, including the Procedure for Community-Based Fire Management in 2011, with the support of local and international organizations. However, these measures have not been adequately implemented, resulting in an increase in wildfires.

The 2012 revision of the Forest and Wildlife Policy also did not bring any change to the situation. A critical review of this policy (strategic direction 1.6) indicates a lapse in addressing the challenges of wildfire control, with an absence of explicit directives as to how logistical support for fire control will be made available. Furthermore, the management framework that is meant to address challenges to fighting wildfires includes sensitization and training on reactive mechanisms (e.g., creating firebreaks) only after a wildfire is reported.

The Ghana National Fire Service Act, 1997 (Act 537) was also intended to provide for the management of uncontrolled fires and make provisions for forest fires. However, the Act was flawed with respect to wildfire management as it was highly skewed towards industrial and domestic fires, rather than wildfires. Overall, Ghana's existing legal policies on forestry, wildlife and environmental management do not include adequate explicit measure to prevent and manage wildfires (Husseini et al. 2020).

Community engagement in effective fire use and wildfire prevention in Atebubu-Amantin Municipal District. Photo: Joseph Asante

Training of community fire volunteers in Atebubu-Amantin Municipal District. Photo: Daniel Kofi Abu

Applying community fire management approaches

Collaborative and adaptive community fire management was introduced to ten charcoal-producing communities as part of the Forest Landscape Restoration through a Sustainable Wood Energy Value Chain project. It was implemented jointly in 2020–22 by GIZ, Ghana's Ministry of Lands and Natural Resources, and the Ministry of Energy, in partnership with IUCN NL and three local implementing partners: IUCN-Ghana, Tropenbos Ghana, and A Rocha Ghana. The project worked with landowners and smallholders to restore forest landscapes in Bono East (Kintampo and Atebubu communities) and Savanna (Mole National Park) regions, which are prone to bush fires. It built on previous work in these areas by Tropenbos Ghana and partners on forest protection, agroforestry and restoration.

The project's specific objectives were to support reforestation for sustainable wood energy production on degraded land, rehabilitate degraded parts of forest reserves, and improve energy efficiency. The experiences gained were used to inform the implementation of the national climate policy and REDD+ strategy, and contributed to the improvement of the framework for sustainable forest management and climate adaption and mitigation.

The project took an approach to fire management that was adaptive and inclusive. The approach involved the development of community fire-management structures, including the establishment of community fire volunteer groups. Stakeholder collaboration was ensured at the community, district and national level, because neither community- or district-level stakeholders can implement effective fire use and management in isolation. Collaborative action included the participation of communities in accepting and adopting effective practices of fire use and management, with the capacity to integrate fire-use and management plans in their land-use activities.

Capacity building in current fire use and management practices included forming a fire volunteer group in each community and in the community at large, for farmers, charcoal producers, traditional authorities, schoolchildren, etc. Capacity development for the fire volunteer groups included training in fire detection and suppression, use of a fire danger rating system to provide indications of potential wildfires, understanding how fires start, and knowledge of fire behaviour. This enabled the leaders of community fire brigades to develop effective fire pre-suppression and suppression plans to help make decisions on when, where and how to safely control fires.

The approach also targeted post-fire management strategies and climate action, including the restoration of degraded forest areas and riverbanks, and integrating trees on farms. The rationale was to support communities to take steps to improve target areas while also ensuring that fire-prone areas have the capacity to recover after wildfires.

Furthermore, a comprehensive incentive mechanism was introduced to encourage communities to participate and to establish a sense of local ownership of and responsibility for fire management. This included support

for community tree nurseries by engaging local people to supply tree seedlings for the restoration of degraded areas and for on-farm planting. Other incentives included providing firefighting equipment, communication tools and mobility support to community fire volunteer groups, so they were able to mobilize and respond promptly to fire emergencies.

Positive outcomes

The target communities collaboratively developed and implemented restoration and fire management plans, including detailed hazard analysis and incidence of fire ratios. The plans defined the actions to be taken to control fire and continuously maintain restored areas. This inclusive approach to fire management enhanced community involvement in decision making and fire planning. It has led to other stakeholders collaborating with them in fire use and management, including farmers, traditional authorities and state institutions. As a result, communities have much more capacity to engage in discussions on fire use and management, and that has positioned them as strategic participants for future engagement. Another key outcome is an increase in tree and forest cover in target areas. Participants planted more than 500,000 tree seedlings during the course of the project, covering more than 250 hectares (ha). This will ultimately contribute to climate change mitigation and adaptation efforts while also improving conditions for other livelihood activities, particularly farming.

Landscapes within the project's target areas were in zones of moderate to high or very high fire risk (Figure 1). One project result has been the reduction of wildfires during the intervention period (2020–22), particularly around sacred groves and restored sites. The communities have thus worked to safeguard their land against wildfires, including restored forests, farms and parklands. This achievement is attributed to the communities' adherence to local rules on fire use and management, supervision by volunteer fire groups of fire use during land preparation, and prompt reporting of and responding to fire outbreaks. It is expected that communities will sustain these strategies and response systems and continue to manage fires effectively.

As one community member said, "...we cannot live without fire: we must learn how to collectively manage it." Meeting long-term dry forest restoration goals will require increases in prescribed and well-managed burns that pose minimal ecological and social risk. The key trade-off associated with dry forest restoration concerns the balance between the scale of restoration and the level of fire resiliency.

Conclusions

Forest landscape restoration and fire management are inextricably linked, particularly in Ghana's transitional zone and in the drier areas in the north of the country. Any attempt at FLR therefore must include an effective system of fire management. Collaborative and adaptive community fire management — that strengthens

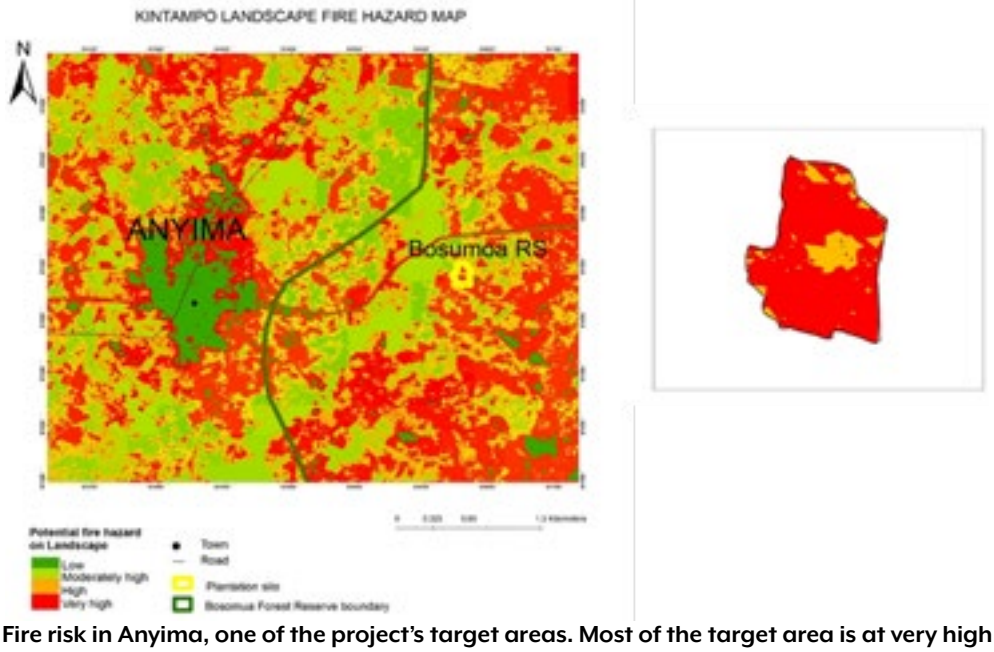

Figure 1: Fire risk in Anyima, one of the project's target areas. Most of the target area is at very high fire risk. Source: GIZ Forest Landscape Restoration Project, 2020.

local capacity and ensures local inclusion through appropriate incentives — has proven to be effective. This is key in reducing the menace of wildfires that threaten communities in the transitional zone of Ghana. Fire use and fire management under the project's approach is making progress toward restoration and climate adaptation goals, improving the alignment of forests' structural mosaic and re-establishing and stabilizing fire-vegetation feedback. However, efforts are required to drive this inclusive approach in fire management at scale; policy makers must initiate reforms to make fire laws and regulations more workable and easily implemented.

Like most disasters, when the smoke clears, questions are raised; in particular, what could have been done to minimize such events, and the associated risk? Past studies and wildfire mapping in Ghana have identified incentives and fire management training as key to effective collaborative and adaptive community fire management. These findings shaped Tropenbos Ghana's fire management approach in the country's transitional zone, based on the understanding that communities who are endowed with knowledge on fire use and management can therefore assess and manage fires effectively. Core to this is strengthening communities' capacity to understand fire and actively participate in its management, while also providing incentives such as suitable firefighting equipment, communication tools and mobility support.

Beneficiary communities can now effectively engage with other actors in fire use and management dialogues, and have practically demonstrated effective fire management capability by successfully safeguarding 252 ha of restored forests, riparian zones and agroforestry parklands. Evidence from this adaptive and collaborative community fire management initiative shows that communities can effectively and efficiently use and manage fires if they have the support they need. This includes enhanced capacity in contemporary fire management practices for all relevant actors, coupled with policy and regulatory reforms that stress multi-stakeholder inclusiveness in fire management at scale.

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4.6

Fires set by farmers in Murchison National Park. Photo: © Dennis Wegewijs - stock.adobe.com

Supporting effective fire management in Uganda

Michael Opige, Richard Ssemmanda, Grace Nangendo, and Joseph Mutyaba

"Managing wildfire risk requires concerted efforts to strengthen capacities and effective coordination between government authorities, the private sector and local communities."

Introduction

Most wildfires in Uganda occur in savanna parks and neighbouring forest reserves. Nearly all wildfires are human-caused, and some landscapes that once burned only at fairly long intervals are now burning multiple times within a 10-year period. This hinders succession and degrades ecosystems. Human-set fires, either in context of land use, accidental or intentional, pose a significant risk to biodiversity and to adjacent communities and their livelihoods.

The impacts of fire on natural ecosystems and wildlife in Uganda began to be recognized in the 1960s, in response to the need for a comprehensive strategy for fire management. The concept of a comprehensive strategy was first introduced for the savannah parks in the 1980s and 1990s, when the management of the Game and Fisheries Department concentrated their efforts on understanding the ecological aspects of the fire regime.

In the early 2000s, however, the Uganda Wildlife Authority (UWA) began to commission studies to assess the immediate effects of fires on the distribution and movement patterns of wildlife. Other work has shown the impact of fire on specific national parks and other protected areas (e.g. Plumptre et al. 2010).

Today, Uganda has a legal and policy framework to protect forests and other wildlife areas, but implementation is weak and laws are unevenly enforced. Also, protected area authorities do not have clear and well-developed strategies for combating wildfires. This article presents the context of fires in Uganda, past and current management, with the West Nile, Northern, and North eastern regions as a case study, and identifies challenges and key needs in moving forward in the development of effective fire management.

Fires in Uganda

Between 2003 and 2012, the annual area of forest burned varied from a high of 293,920 ha in 2003 and a low of 35,670 ha in 2008. About 1.4 million ha of all land burned in 2021 but this is normal, compared to previous years since 2001, with a record of 7.3 million ha in 2005. Uganda reported that 550,000 ha of forest alone were burned in 2000 (MWE 2017) and that the highest non-CO2 emissions from forest wildfires were from carbon monoxide, most of it attributable to burning woodlands.

Satellite images from 2000–12 were analyzed by the authorities, in order to zone areas prone to wildfires and generate a fire hazard map of Uganda (Figure 1). These images were obtained from the Regional Centre for Mapping of Resources for Development (RCMRD) in Nairobi. A total of 20 districts are at very high risk of wildfires; 13 districts are at high risk; and 17 are at medium risk. The Northern Region has the highest risk of wildfires, followed by parts of Teso sub-region, Rakai District and West Nile sub-region.

Some pastoralist and livestock-rearing communities use fire to burn pasture land. However, these fires can spread, and some have started disastrous wildfires. For example, a fire in January 2012 destroyed many acres of vegetation in the Pian Upe Wildlife Reserve. In February 2012 a fire displaced 24 families in Moyo district. In April 2012 a fire destroyed pasturelands in Karamoja sub-region.

Fire management in protected areas

Following efforts to recognize the impacts of fires in the 1960s, the approach was revamped in the 1980s and 1990s, when the management of public land in government estates concentrated on understanding the ecological aspects of fire regimes. In the early 2000s, UWA commissioned a study to understand the immediate effects of fires and burned areas on the distribution and ranging patterns of wildlife (Jaksic-Born 2004). This contributed to a more comprehensive understanding of how fire regimes influence herbivores' movements and habitat use, particularly with regard to fire management decision making and strategies for protecting natural habitats. However, whereas the ecological aspects of wildfires are now better understood, more work is required to assess the impacts of wildfires on communities and their livelihoods.

Fire management measures in Uganda were introduced by the Uganda Wildlife Authority in 2005, applying

Fire Incidence, 2010–20 **Fire Incidence, 2020**

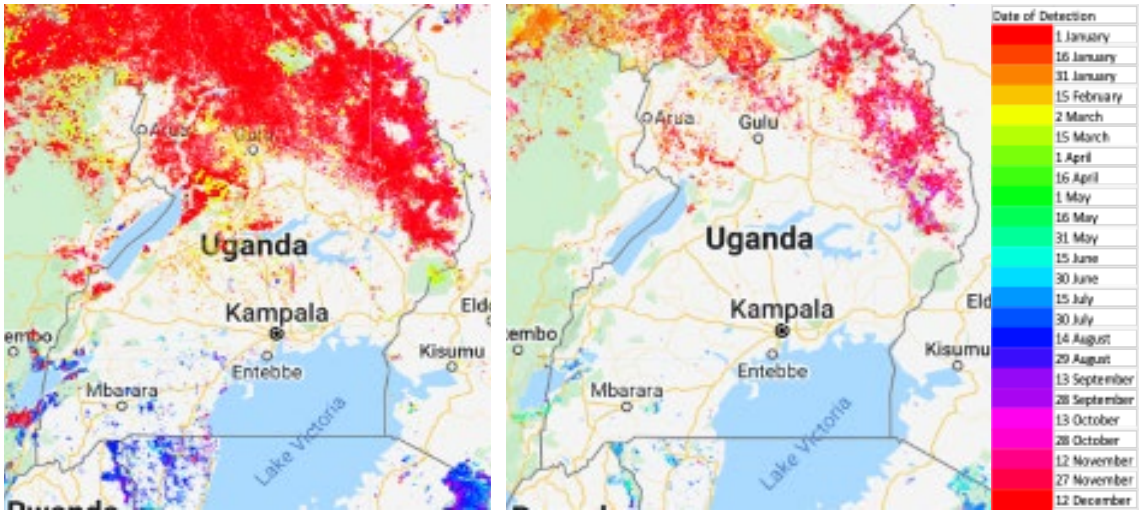

Figure 1: Fire incidence in 2010–20, and in 2020 alone. Source: Google Earth

controlled early burning in selected areas and creating fire barriers to act as firebreaks (Nangendo 2005). However, the effectiveness of these measures was not assessed. The National Forestry Authority also established firebreaks on the boundaries of some forest reserves, but they appear to be ineffective and are poorly maintained. Controlled and selectively applied early burning has now been used for 20 years by conservation managers as a tool for eliminating dry biomass and to maintain patchy vegetation. This builds on traditional fire use by farmers and pastoralists for bush clearing, pasture management and hunting, especially in the drier North, North western and North eastern regions. From these practices, lessons learned can be used to develop effective strategies. See Box 1.

Types of fire use in Uganda

Bush burning in traditional land management

Bush burning is used as a land management practice to clear land for cultivation (especially in the drier northern areas of the country), and coincides with the first rains of the season. This is also the time when hunting, especially of rodents, is common among the local communities.

Fires in traditional rangeland management – in the "cattle corridor"

Uganda's cattle corridor is the central pastoral belt that extends from Karamoja to Teso through the central districts of Kayunga, Nakasongora, Mubende and south through Mbarara and Rakai districts, which border Tanzania. In the corridor, fire has traditionally been used to clear grazing land of shrubs, to control ticks, and to allow new grass to sprout when the rains begin. If not overly frequent, fire also tends to maintain the existing vegetation structure, rather than causing changes in habitats. However, integrated fire management, as practised in protected areas and in timber plantations (e.g., Nakasongora District), appears to require additional incentives for people to adopt it in rangelands, especially as fire use is traditional there.

Box 1. Fire in the Albertine Rift

Wildfires are especially common in savannah parks such as Murchison Falls National Park in the Albertine Rift, western Uganda, where people regularly set fires to refresh grass for livestock, and for hunting wild animals. Fire has been singled out as a key element in determining the vegetation structure and floristic composition of such mosaic landscapes (Nangendo 2005). Increasing fire frequency results in decreased tree cover and a transition to more fire-resilient shrubland and savanna; however, controlled fires are essential in the management of savannah parks.

Adjoining Murchison Falls National Parkare Budongo and Bugoma forests, covering 80,000 ha and 40,000 ha, respectively. Both under central government protection, they are situated in a mosaic of forest, woodland and grassland, along with farmers' fields and areas of bush fallow. People set fires within forests and woodlands to clear land for cultivation, promote new growth, and harvest honey, but these fires often spread out of control and burn large areas. This impairs the regeneration of some trees, and forests may gradually be replaced by savanna. Fire also has impacts on wildlife, by killing animals, and indirectly by affecting species composition (Nangendo 2005). Fires also have both direct and indirect effects on communities and their livelihoods.

In Budongo Forest, early burning has long been recommended by the Forest Department for controlling bush encroachment and reducing risks to wildfire. It has hardly ever been practised, however, due to inadequate staffing at forest stations, and a lack of explicit fire-management plans. Unfortunately, the situation has not improved since the National Forestry Authority was established in 2003. Uncontrolled fires have become a major concern, but neither the National Forestry Authority or the Uganda Wildlife Authority are well equipped to prevent them, and once wildfires ignite, these agencies cannot control them.

Furthermore, there are new activities with the potential to cause more wildfires in the national park, including the exploration and exploitation of oil and gas reserves, expanding agrocommodity production (mostly sugarcane) and more pine and eucalyptus plantations. Other wildfire sources include fires set to clear land and bush for refugee resettlement in the area. The risks from all these activities are worsened by the current climate trends towards more prolonged dry spells. They worsen the wildfire risks to local communities and their livelihoods, and to the conservation of forest estates and biodiversity in the region. It is thus essential that a fire management strategy be developed and implemented.

Traditional controlled fires – in forests

Hunting and gathering are carried out in forests, especially by communities using rudimentary methods. Hunters and gatherers are encouraged to limit the use of fire; for example, by measures such as smoking vegetation rather than burning it during honey collection, and by collecting only during wet seasons.

Traditional controlled fires – in farmland

Burning fallows and agricultural residues reduces the labour needed to clear farmland before planting. It is a common practice in the northern and northeastern parts of the country. The risk of escaping wildfire can be reduced by using alternative mechanical methods other than fire to clear agricultural plots for planting if these plots are adjacent to forests, parks or other protected areas.

Controlled burning – in savannah parks

The Uganda Wildlife Authority promotes carrying out controlled burning at the end of the wet season so that fires are less intense. The size of areas to be burned is arbitrary, depending on boundaries such as rivers, swamps, gullies, roads and tracks that act as firebreaks. In some instances, firebreaks have been established, but are poorly maintained. It is essential to create a barrier through early burns along park boundaries to prevent fires from entering areas that are outside the control of the park authorities.

Malicious fires – in forests and plantations

Some fires are set intentionally by hostile communities, in retaliation for a refusal to allow them access rights, in order to use parts of the area to grow food crops, graze livestock or collect forest products. Malicious fires are also set for other reasons, such as land conflicts between communities and agrocommodity companies, low prices for outgrower communities (where fires are set on the nucleus estates) and criminal use to terrorize communities.

Lessons learned

Reducing human-caused fires will greatly minimize landscape impacts

Fire prevention greatly reduces the resources needed for fire suppression. Prevention programmes exist, and need only to be rolled out. Examples include the promotion of alternative methods to clear land for planting if plots are adjacent to forests, parks or other protected areas; awareness raising among communities to limit the use of fire for hunting and honey collection; promoting collective responsibility for and understanding of the impact of fires; and providing incentives for forest-adjacent communities. The last is especially important where fires are deliberately set to destroy forests and plantations because of disputes about access rights.

Implement existing guidelines for developing fire management plans for protected areas

Accidental fires occur during controlled burning programmes. UWA developed a set of guidelines that outlined how to categorize areas into risk zones; they also provided strategies for early burning and wildfire suppression, discussed the technical aspects of firefighting, and provided a template for a fire management plan (see DeMeo et al. 2010, Appendix D, for an annotated copy of the template). Fire management plans following this format have been developed for some national parks under wildlife crime prevention plans, including Queen Elizabeth National Park (2017–23) and Murchison Falls National Park (2017–23).

Involve all stakeholders

Many disparate groups need to come together and work on fire risk management planning and the preparation of a strategy and implementation guidelines. The following must not be omitted (but this list is not exclusive): communities living in and around fire-risk areas, National Environment Management Authority, National Forestry Authority, Uganda Wildlife Authority, Office of the Prime Minister, oil and gas companies and agrocommodity companies whose activities may start fires and whose assets are at risk from fires, the Petroleum Authority of Uganda, National Oil Palm Project and related national bodies.

Identify the fire management needs and capacity of concerned authorities

Undertaking a detailed gap analysis will improve the understanding of the capacity challenges faced by each department, organization and group included above. These gaps need to be addressed by implementing tailored training to meet short-term and long-term needs, and the provision of appropriate equipment where required

Develop fire management planning processes at local, landscape and national levels

Effective planning requires a holistic approach, rather than disjointed efforts, and there is an urgent need for effective coordination of wildfire management activities. This should come through a bottom-up approach, where stakeholders at the landscape level come together under

a common platform; this should later transform into a national platform. Given the inadequacy of information about wildfires, research at the landscape level should be useful to stakeholders, who can then participate in a national-level platform to better inform policy and guidelines.

Conclusions

Understanding fire ecology is a primary consideration in developing and implementing fire management planning processes. Land capability, including climate, drives the types and sizes of fires. It is very important to acknowledge these differences in order to plan effectively. For example, some high-risk forests must be protected from wildfires, whereas in savanna ecosystems, fire plays an integral role. It is also essential to improve the understanding of the human use of fire, and to develop and implement guidelines for all stakeholders that align with their respective management priorities. Last, there is need to assess the needs of the key stakeholders in managing wildfires, and where appropriate, equip them with skills and equipment to manage risks.

Complementing this are three overarching considerations, as the country moves forward to developing, adopting and implementing an effective fire management strategy: communication, collaboration and coordination.

- *Communication*: to disseminate knowledge and understanding of wildfires causes and impacts to all actors at all levels, so this can be built into both planning and operational processes.
- *Collaboration*: to initiate a fire management planning process that involves key partners and stakeholders, and includes local communities, to jointly develop both landscape-wide and site-specific forest and wildfire management plans. Community engagement and awareness must be central to all efforts, and stakeholder platforms, which are valuable for building relations within a landscape, need to be developed.
- *Coordination*: to strengthen inter-agency coordination and build a strong working relationship between state and non-state actors. Government agencies, the private sector, civil society and local communities must work together in order to make effective fire management plans. Concerted and coordinated planning should then lead to the development of a national fire management strategy, to be adopted by the National Environment Management Authority and enforced as policy in consortium with other government agencies.

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4.7

Identifying the extent of burned areas is essential to plan the necessary post-fire restoration measures. Photo: Harifidy Rakoto Ratsimba

Using satellite images to monitor burned areas in Madagascar

Gaston Hedwigino Tahintsoa, Dimby Raherinjatovoarison, Haritiana Zacharie Rakotoarinivo, Rajira Nambinintsoa Ratsimandresy, and Harifidy Rakoto Ratsimba

"Fire monitoring through mapping of burned areas has a crucial role in designing appropriate fire management programmes."

Introduction

The conservation of Madagascar's unique natural heritage is a key concern of public authorities, and also attracts the attention of international organizations. One threat to the country's flora and fauna is the recurrence of wildfires. It is true that many of the country's forest landscapes have long been shaped by fire, but the increase in fire frequency and in the total burned area is having ever more negative impacts on ecosystems. Wildfires also affect livelihoods by burning the forests and even the farmland that people depend on. However, effective fire management remains a major challenge for natural resource managers in the country. A prerequisite is to first understand the extent of the problem, in order to plan both adaptation and response strategies. This requires accurate quantitative data on when and where fires are burning.

Since 2000, satellite monitoring of fires in near real-time has been widely popularized and used in Madagascar, mainly in and around protected

The ground covered with ash in an area recently burned by a very-high-intensity fire in Ankarafantsika National Park. Photo: Dimby Raherinjatovoarison

areas. It has been used primarily to trigger alerts as part of early warning systems to increase the timely mobilization of firefighting responses. However, limitations have become apparent, especially in analysis of the impacts related to the frequency and extent of fires on the same burned surfaces.

This article reports on a study carried out in 2021 over an area of 1,575 ha in and around Ankarafantsika National Park in northwestern Madagascar using satellite images, drone images and ground-truth data to assess the accuracy and usefulness of mapping in quantifying burned areas. During that year, 13,073 ha were burned in the park (about 10% of its total area), predominantly in September and October. The park is not only home to exceptional biodiversity, but also plays a role in the economy of Boeny Region as a water regulator for the plains of Marovoay, one of the main rice-producing areas in the country. As a result, its protection and conservation are essential.

Quantifying burned surfaces

Burned areas are characterized by deposits of charcoal and ash, removal of vegetation, and change in the structure of vegetation (Boschetti et al. 2006). This leads to a change in the spectral behaviour of surfaces in time and space that can easily be tracked by remote sensing.

Images with low and medium spatial resolution are used to develop tools for monitoring burned surfaces. Many are taken by the Advanced Very High-Resolution Radiometer (AVHRR), the Geostationary Operational Environmental Satellite (GOES), and the Moderate Resolution Imaging Spectroradiometer (MODIS). MODIS is the most widely used sensor because it has the highest spatial resolution (500 m) and can detect active fires and thus allow decisions to be made quickly. However, even with its high resolution it is difficult for users to detect the extent of small fires, which are very frequent in tropical environments. The launch of Landsat 8 OLI in 2013 (30-m resolution) and Sentinel-2 MSI in 2015 (10-m and 20-m resolution), allowed the use of sensors with better spatial resolution (Mpakairi et al. 2020).

Evaluation of three sensors

Analyses in the study were carried out using MODIS, with the latest MCD64A1 collection, Landsat 8, and Sentinel-2. Images were acquired for the south of Ankarafantsika National Park between 15 and 17 October 2021 following specific fire events observed in the field. MODIS images from October 2021 were downloaded from the EarthExplorer platform and those from Landsat 8 and Sentinel-2 were directly processed and classified in the Google Earth Engine Cloud platform.

Spectral indices were used to better discriminate burned areas in satellite images; a combination of two or more indices improved classification (Bastarrika et al. 2011). Two common indices were used: (i) the Normalized Burn Ratio (NBR) and the Burned Area Index (BAI) for Landsat images; and (ii) the NBR and BAIS-2 (the improved version of BAI) for Sentinel-2 images (Filipponi 2018). As with other

normalized spectral indices, the theoretical value of NBR varies between 1 and –1: a high value indicates good vegetation condition, while a low value indicates bare soil or a burned area (Key and Benson 2003). BAI does not have limit values, but in general, higher values indicate burned areas (Chuvieco et al. 2002); the index performs better in forested areas, where it highlights ash deposits (Mpakairi et al. 2020). For Landsat images, burned areas generally have an NBR between 0 and 0.3, and a BAI above 70 (Stroppiana et al. 2002). For Sentinel images, burned areas have an NBR lower than 0, and a BAIS-2 value higher than 0.87.

Results were then validated in three steps:

- First, field validation was undertaken to assess any errors related to the identification and estimation of burned areas. For this purpose, ground-truth data was recorded from 89 GPS points (Figure 1), a proportion comparable to studies in similar biogeographical areas (e.g., Axel 2018).
- Second, three error parameters were calculated to compare the performance of MODIS, Landsat 8 and Sentinel-2 sensors: error of omission (i.e., under-estimates), error of commission (i.e., over-estimates), and overall accuracy.
- Third, the three sensors were compared to true-colour images obtained from a flyby of a Mavic 2 pro quadcopter drone at 100-m altitude, with a spatial resolution of 5 cm, to evaluate any errors on the edges of burned areas due to the difference in spatial resolution of the sensors (Figure 2).

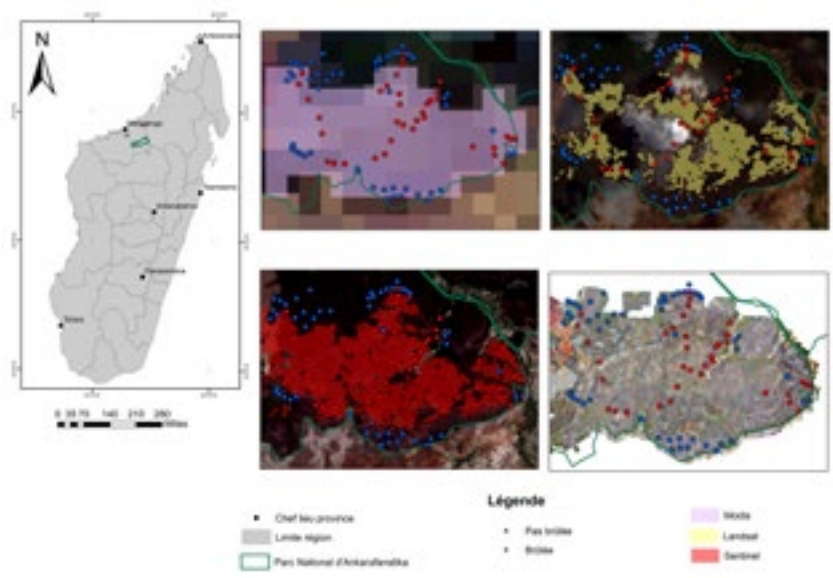

Figure 1. Field data used to validate burned area mapping from MODIS, Landsat 8 and Sentinel-2 in Ankarafantsika National Park.

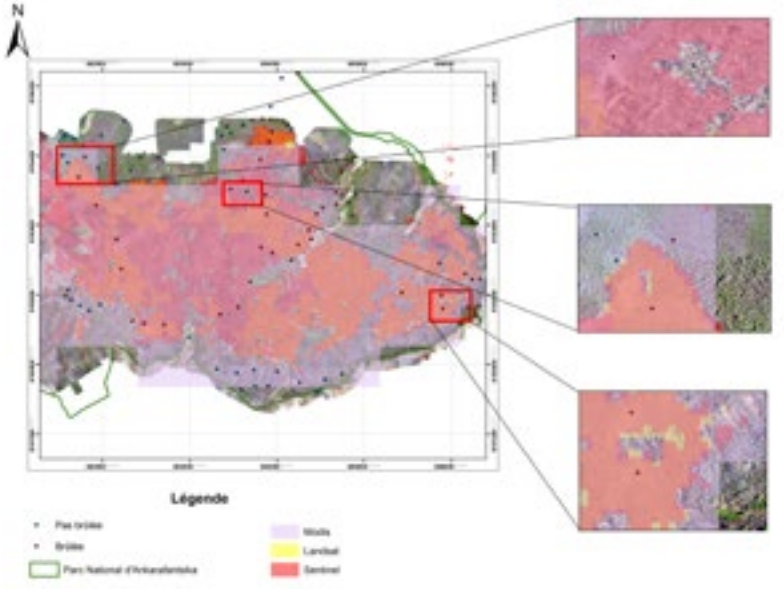

Figure 2. Errors observed on the edges of burned surfaces from MODIS, Landsat 8, Sentinel-2, compared to UAV true-colour images.

Aerial images allow users to determine the size of burned areas. Photo: Gaston Hedwigino Tahintsoa

Over an area of 1,575 ha in Ankarafantsika National Park, the three satellites gave very different estimates of burned forest, with 1,181 ha reported by MODIS; 330 ha by Landsat 8; and 656 ha by Sentinel-2. A comparison of commission error, omission error and overall accuracy was then required in order to accurately estimate the total burned area.

The MODIS sensor had a high commission error (57%) compared to Sentinel-2 (10%) and Landsat 8 (4%), meaning that more than half of the burned areas it detected were not actually affected by fire and were thus considerable overestimates. In contrast, Landsat 8 tended not to recognize many burned areas, having by far the highest omission error (73%), compared to Sentinel-2 (27%) and MODIS (16%). The cause of this error may be due to cloud cover on the image, or to underestimations linked to the presence of standing trees after fires.

Aerial images from the drones corresponded consistently with the ground data. The causes of the omission and commission errors from the three sensors were then revalidated using the UAV true colour images. Most errors were observed at the edges of burned areas on UAV images (Figure 2), and were undoubtedly linked to the difference in spatial resolution (500-m for MODIS, 30-m for Landsat, 10-m for Sentinel-2, and 5-cm for UAV images). Ground validation and the UAV images also showed that surface fires that do not reach treetops, leaving the treetops green, are not detected by Landsat and Sentinel images.

The Sentinel-2 sensor largely outperformed the other two sensors, with an omission error of 27%, a commission error of 10% and overall better accuracy of 83%. Sentinel-2 also had better spatial (10-m and 20-m) and temporal (5-day) resolution. Moreover, Sentinel-2 images are also free of charge and can use 13 spectral bands. In addition, the probability of having a time series of images even with low cloud cover is greater with Sentinel-2 than with Landsat.

Applying the methods

Based on these results, a monthly analysis of burned areas in the whole country is now made using Sentinel-2 images and the mapping method used in this study; the results are made freely available by the Regional Eastern Africa Fire Management Resource Center (REAFMRC). The centre was established at the Land, Landscape and Development Research Lab at the University of Antananarivo, with the assistance of the Global Fire Monitoring Center (GFMC).

The open-access geoportal of REAFMRC allows fire information to be shared with all stakeholders, from members of the public to policy makers. To support this, REAFMRC organized workshops at the end of 2021 and the beginning of 2022 with the Ministry of Environment and Sustainable Development at the national and regional level for geoportal designers and users from national public and private institutions working on the management of fires and natural resources. One of the first observations following the launch of the

geoportal was the reduction of almost 1,000,000 ha in total area burned nationally in 2021 (4,397,342 ha) compared to 2020 (5,380,250 ha). This reduction is linked to the increased presence of the ministry in charge of environment at the local level, and the mobilization of stakeholders in active fire protection and prevention.

Since 1997, satellite remote sensing has increasingly been used to collect information on burned areas. Mapping of burned areas — based on satellite images such as Sentinel-2 — has become an operational tool that facilitates decision making by those responsible for fire management. It provides valuable information for all actors responsible for the management of fire and burned land, through a rapid, accurate and economical estimate of burned areas. Indeed, even if field measurements generally give more accurate estimates of burned areas, they can be difficult to carry out, due to the lack of accessibility of certain burned areas, the considerable time needed to estimate a large burned area, and the significant human and material resources that need to be mobilized.

The technique discussed here makes it possible to quickly locate priority intervention areas for conservation or for planning restoration protocols. In Ankarafantsika National Park, the information provided by satellite data has enabled the park manager to develop, in collaboration with the Ministry of Environment and Sustainable Development of Madagascar, a five-year plan for the restoration of areas affected by fires. The plan will be implemented with local communities, and supported by local environmental organizations and village nurseries that will provide seedlings of forest species for planting. This will not only enrich the park with woody species that are less sensitive to fire and thus reduce the risk of fires in the park, but will also increase local income through the sale of seedlings.

Conclusions

Mapping the extent of fire-affected areas is very important for integrated fire management, especially for stakeholder communication and mobilization, rehabilitation of burned areas, and decision making. Scaling up this type of process allows the development of systematic detection of monthly and annual burned areas, making it possible to calibrate potential fire management responses in open and forested landscapes.

Based on the successful use of satellite mapping data in Madagascar, the REAFMRC geoportal is being extended to cover all East African countries. A first step has been taken: comparing the approach with that of the European Space Agency (which measures burned areas covering all of Africa using Sentinel-2 images, but which is only available for 2019; see Roteta et al. 2019). As of 2023, the geoportal will include the burned areas of a dozen East African countries. The second stage of validation will be carried out with the cooperation of local fire management stakeholders and will be based on field validation.

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