# PARTNERSHIPS FORGED IN FIRE

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PRISMA

Programa Regional de Investigación sobre Desarrollo y Medio Ambiente

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# Executive summary

The world is heating up. Globally, the average temperature has increased by 0.85 °C since 1880; it could rise by another 3 °C or more by 2100 if the concentration of greenhouse gases in the atmosphere continues to escalate. One of the consequences of global warming is an increase in the risk posed by wildfire – California suffered its most destructive fire season in history in 2017. Extended droughts in the Amazon in 2005, 2010, and 2015 brought significant fires. Haze from forest fires in Indonesia affected neighboring countries in 2015. Worldwide, fire seasons are becoming longer and the number of wildfires is growing.

The best firefighting equipment in the world cannot stop – or even slow down – the most devastating wildfires. On the other hand, innovative fire prevention measures can mitigate the damage and reduce the cost of putting fires out (the United States Forest Service, for example, now spends more than half its annual budget – nearly USD 4 billion in 2016 – fighting fires).

An effective weapon to prevent uncontrolled wildfire is knowledge. And, in fire-prone landscapes, an untapped source of fire knowledge is in the hands of those who have been living there all along. Indigenous Peoples have been using fire to manage their environments for thousands of years. Their customary tenure extends over an estimated two-thirds of the world's land area, and indigenous lands contain at least 24% of the world´s tropical forest carbon.

Now, fire management agencies, Indigenous Peoples and local communities are starting to collaborate, pooling their different sets of knowledge and capabilities to manage and reduce the threat posed by wildfire. Such partnerships, involving Traditional Fire Knowledge, could become even more important if global temperatures continue to rise.

This report examines the emergence of collaborative – or "intercultural" – fire management between professional fire managers and traditional and Indigenous Peoples in California, Guatemala and Brazil. It summarizes scientific studies on the increasing threat posed by wildfires worldwide, and the fire practices of Indigenous Peoples and local communities. And it makes the following four recommendations to facilitate such integrated approaches to fire management:

- Address legal and political constraints on the land tenure, access, and stewardship of Indigenous Peoples and local communities to empower them to maintain their Traditional Fire Knowledge and practices and enable fully collaborative approaches to fire management.
- Strengthen the next generation of fire-knowledge bearers by helping young members of indigenous and local communities to apply the fire wisdom and practice of their ancestors, and by supporting training in intercultural fire management.
- In scientific research, value the Traditional Knowledge embedded in indigenous oral histories and evaluate the outcomes of traditional fire practices.
- Build intercultural fire management partnerships involving indigenous and local communities, professional practitioners, regulatory agencies and researchers that enable the sharing of knowledge, wisdom, and toil and are based on trust, mutual respect, and honest communication.

# Introduction

The planet has been besieged by wildfire this northern summer. At the time of writing, in early August 2018, at least 91 people had recently died in fires in Greece;[1] Sweden was having one of its worst fire seasons on record, with even the Arctic Circle ablaze;[2] and 75 large fires were scorching the United States.[3] Earlier, in April, wildfires had ripped across the Russian Far East at a rate of 20,000 hectares a day.[4]

The world is heating up. Globally, the average temperature has increased by 0.85 °C since 1880; it could rise by another 3 °C or more by 2100 if the concentration of greenhouse gases in the atmosphere continues to escalate.[5] One of the consequences of global warming is an increase in the risk posed by wildfire – California suffered its most destructive fire season in history in 2017.[6] Worldwide, fire seasons are becoming longer and the number of wildfires is growing. Despite this, more and more people are building homes in fire-prone environments, increasing the loss of life and property due to wildfire.

The best firefighting equipment in the world cannot stop – or even slow down – the most devastating stages of fast-moving wildfires. The Tubbs fire, which burned in two Californian counties in 2017 and killed 22 people, was "like a blowtorch," according to Scott McLean from the California Department of Forestry and Fire Protection (CAL FIRE). "We could've put every piece of equipment in its path and that fire would've gone over it, under it, through it. It wouldn't have mattered."[7]

The cost of firefighting is mounting, too. The United States Forest Service, for example, now spends more than half its annual budget – nearly USD 4 billion in 2016 – fighting fires.[8]

The most effective weapon against wildfire is not a rake hoe, a ground appliance, or a water-bomber – it's knowledge. And, in fire-prone landscapes, the greatest untapped sources of fire knowledge and sustainable fire practice are the peoples who have been there all along.

Indigenous Peoples have been using fire to manage their environments for thousands of years, and they hold deep wisdom and insight. Now, fire management agencies, Indigenous Peoples and local communities are starting to collaborate, pooling their vast knowledge and capabilities to manage and reduce the threat posed by wildfire.

This report examines the emergence of collaborative – or "intercultural" – fire management. It summarizes scientific studies on the increasing threat posed by wildfires worldwide, the fire practices of Indigenous Peoples and local communities, and recent collaborations between professional fire managers and traditional peoples in California, Guatemala and Brazil. The early signs are that these unlikely alliances offer one of the best ways forward for fire management in an increasingly hot world – with the upholding of the rights of Indigenous Peoples and local communities to their ancestral lands a crucial ingredient for success.

# Climate change is increasing the threat of wildfire

In previous decades in California, big wildfires tended to start only in autumn after hot, dry summers. But blazes in Yolo County this June were indicative of a deeply worrying trend.

"Fire season doesn't seem like the right term to use anymore. The new normal for us is nearly a year-round fire season," says Chris Anthony, a CALFIRE division chief. "Twenty-two thousand acres in less than 24 hours at the end of June is not a good sign of things that might come."[9]

Climate change is bringing warmer, drier conditions and lengthening fire seasons. From 1979 to 2013, the fire weather season increased in length by an average of 18.7 percent across about one-quarter of the Earth's vegetation surface (29.6 million $km^2$).[10] This metric, and the area of land affected by long seasons of fire weather, increased significantly on all continents[11] except Australia (which showed no significant trend) over the period.

There has been a marked increase in the frequency and duration of large wildfires in the United States in recent decades, attributed largely to a shift towards earlier snowmelts. An early snowmelt tends to lead to an earlier, longer dry season, which, in turn, provides more opportunities for large fires, both because of the longer period in which ignitions can potentially occur and because soils and vegetation dry out more.[12]

The number of large fires trended higher between 1984 and 2011 in seven of nine ecoregions in the western United States. Across all nine of these ecoregions, there was an overall increase of about seven large fires per year over the period, and the total burnt area increased across the nine ecoregions by a rate of 355 $km^2$ per year.[13] The average yearly number of large wildfires on federally managed lands in the 11 western states increased by nearly 80 percent between 1980–1989 and 2000–2009, from about 140 to 250.[14]

A study of extreme fires in the northwest United States found that widespread fire periods occurred in years in which weather patterns departed from historical climate norms.[15] Human-caused climate change[16] has accounted for more than half the increases in fuel aridity (that is, the dryness of flammable materials) observed in forests in the western continental United States since the 1970s.[17] In five forest areas in the western United States (Northern Rockies, Northwest, Sierra Nevada, Southwest, and Southern Rockies), the average length of the fire season increased from 138 days in 1973–1982 to 222 days in 2003–2012, and the mean burn time (the time between the first discovery of a fire and its control) for large wildfires increased from 6 days in 1973–1982 to 52 days in 2003–2012.[18]

The 2009 Black Saturday wildfires in the state of Victoria, Australia, which caused the deaths of 173 people, occurred during "a severe and protracted drought which [was] without historical precedent."[19] The conditions were terrifying: on the afternoon of Black Saturday, temperatures rose above 46 °C [115 °F] and relative humidity dropped below 10 percent. Strong winds in the morning grew to storm force

as the day progressed, and a change in wind direction moved across the state during the afternoon, greatly intensifying the fires.[20]

> "Witnesses – both firefighters and lay witnesses – compared the sound of the approaching fire to that of jumbo jets or steam trains. One even likened the sound to that of an artillery battle. ... Witnesses described the fires as 'swirling vortexes', with flame heights of up to 100 metres. The fires seemed to create their own wind, which some described as 'cyclonic'. Mr Leigh Jowett said it was as though 'the wind [was] pulling the trees right out of the ground around my house'."[21]

Conditions will get worse: climate change is projected to increase overall fire potential from low to moderate in the United States, central Asia, and southern Europe and from moderate to high in South America, southern Africa, and Australia.[22] The number of high fire-danger days could increase by 35 percent globally by 2050, with potentially sharp increases in the European Mediterranean Basin and Levant, subtropical Southern Hemisphere (Atlantic coast of Brazil, southern Africa, and the central east coast of Australia), southwest United States, and Mexico.[23]

## Land management also affects the threat posed by fire

Humans can influence background levels of natural fires both positively and negatively. Reducing the connectivity and load of fuels, by removing or separating burnable materials in the forest and urban landscapes, can reduce fire spread and intensity. Depending upon the ecosystem in question, practices such as clearing forests, promoting grazing, spreading certain plant species, altering ignition patterns, and actively suppressing fires today can change the character of fires tomorrow.[24] In the western United States, logging, grazing, and the advance of certain invasive plant species, combined with efforts to suppress fires, have caused fuels to build up in some ecosystems, increasing vulnerability to wildfire.[25] The growing urban sprawl has exacerbated the problem: the region's Wildland Urban Interface (that is, land on which homes are built near or within areas prone to wildland fire) grew by 24 percent from 1990 to 2010. This has increased the threat posed by wildfire to people, homes, and infrastructure, with the average annual number of structures lost to wildfire leaping by 300 percent since 1990.[26]

Several high-impact "mega-fires" can be traced to land-management decisions that caused large quantities of biomass to accumulate and fuels to build up over large areas.[27] A study of 478 extreme fires worldwide between 2002 and 2013 found that, although such fires occurred widely and in boreal, temperate, and tropical regions, they were generally absent in biomes with very high rates of landscape fire, such as tropical savannas – in other words, when small fires were common, energetically extreme fires were rare.[28] Prescribed fire (and mechanical surrogates, such as thinning and mastication) in forests in the Western and Southern United States has been shown to increase the resistance and resilience of forests to intense wildfires.[29]

# Traditional fire knowledge is multifaceted, and is fundamentally linked to community rights

Humans have been interacting with and influencing fire regimes for millennia. Indigenous Peoples and local communities, often with deeply embedded cultural knowledge of fire management, continue to manage large areas of land, with legal ownership rights to nearly 900 million hectares worldwide.[30] Customary tenure – most of which is unrecognized by states – extends over an estimated 8.54 billion hectares (65 percent) of the global land area.[31]

Traditional fire knowledge (TFK) is "fire-related knowledge, beliefs, and practices that have been developed and applied on specific landscapes for specific purposes by long time inhabitants".[32] A review of 35 studies of TFK in 27 countries on six continents found 69 distinct elements. Of these, 21 elements (30 percent) were recorded on all six continents, and 46 (67 percent) were recorded on four or more continents. Among the most common elements (included in more than half the studies) were: fire effects on vegetation; season of the year; fire effects on animals; the moisture of live or dead fuels; the onset or end of the rainy season or dry season, or the timing of rain; fire intensity or heat output (i.e. hot or cool fire); time since the last fire; fire control; firebreaks; and the consequences of not burning.[33]

Despite these similarities in TFK among traditional communities worldwide, the many combinations of knowledge elements, and their local variations, mean that individual pyrogeographies[34] comprise both universal and local fire knowledge. The TFK held by communities, therefore, is usually unique to specific environments and cultures. It is multifaceted and often highly sophisticated.

Fire is used traditionally in landscapes for four main purposes: 1) rotational farming involving the clearing and burning of small forest patches; 2) to maintain trees in groves or individually, for example to stimulate fruit production or maintain sacred sites; 3) to promote the growth of grasses and other forage for domestic livestock; and 4) to maintain open country, for example for hunting, gathering, nomadic pastoralism, clearing travel routes, village sites, and communication.[35] Fires are also set deliberately at appropriate times to reduce the risk posed to communities by high-energy fires.[36]

When planning fires, Xavante hunters in the central Brazilian savanna (known as *cerrado*) discuss factors such as season, weather, winds, soil, foliage moisture, type of vegetation, and natural barriers in order to control the intensity of fires and their spatial distribution and frequency. The hunters are mindful of the potential negative ecological effects of burning the same patches of vegetation in consecutive years, especially during droughts.[37]

Some indigenous groups living on the borders between forests and savannas in Brazil, such as the Kayapó, Tupi-Guarani, Krahô, and Bororo, have very refined fire management methods. The Kayapó recognize and manage more than 40 types of forests, savannas, and grasslands, and they use fire to create orchards in which they plant several species of fruit trees and other useful plants. Fire is used to make firebreaks around these orchards to protect them from accidental burns. Specific fire regimes are applied to stimulate the flowering and fruiting of some species and to control plant diseases and pests,

and cool burns are made during the first spring rains to fertilize the soil with ash deposited on soil surfaces while avoiding damage to the plants.[38]

TFK is a fundamental aspect of the rights of traditional communities, and its long-term viability, along with many other traditional activities, often hinges on the security of community land tenure. Such security provides the certainty necessary for communities to know that their investments in the landscape (in time, labor and resources, including the use of TFK) will be reaped locally, and that local lands and resources will not be expropriated by third parties. Recognition of communities as owners of their lands also allows them to benefit from formal representation vis-à-vis other governmental, private or non-governmental organizations – all three cases presented here, for example, involve communities with basic land rights. Since traditional livelihoods frequently depend significantly on local ecosystems, resource use decisions are often made with discernment and intricate knowledge of ecological imperatives. These are some of the main dynamics that underpin the growing body of scholarship that has associated the legal recognition of community rights with enhanced livelihoods and positive conservation outcomes.[39] Other studies have highlighted the role of these communities in fighting climate change, showing that indigenous peoples and local communities hold at least 24% of the world´s tropical forest carbon in their territories[40], while others explicitly link lower carbon emissions with community-owned forests and local rulemaking.[41]

# Fire management by traditional peoples is ecologically adapted and can reduce wildfire

## Temperate forests in the western United States

Traditionally, Native American tribes in California, such as the Yurok, encouraged the growth of certain native species, such as oaks (*Quercus* spp.) and tanoak (*Notholithocarpus densiflorus*), through frequent anthropogenic burning to reduce forest litter, kill pests and pathogens, and facilitate access for the collection of acorns (a staple food in many regional diets).[42] The Yurok used fire for managing trees, clearing underbrush, hunting and trapping game, and protecting villages, houses, and spiritual areas from larger fires by clearing nearby areas.[43]

A study at two sites in the Klamath Mountains in the ancestral territory of the Karuk Tribe found paleoecological evidence that portions of the landscape were managed actively with fire to retain open-forest, shade-intolerant resources, consistent with ethnographic descriptions of Native American land-use management. The same study found evidence that the lack of fire arising from early twentieth-century fire-suppression policies and bans on Native American burning practices produced a closed-forest structure, which is arguably more prone to wildfire.[44]

## Savannas

Interruptions to traditional early-dry-season fire management in savannas worldwide have resulted in high-intensity fire regimes and correspondingly high greenhouse gas emissions from savanna wildfires. On the other hand, the re-introduction of traditional burning practices in remote northern Australia has been demonstrated to reduce emissions by more than one-third.[45]

Fire is a natural phenomenon in the *cerrado* in the central Brazilian savanna: there is evidence of wildfires in this biome as early as 32,000 years ago, long before humans lived in the area.[46] Semi-nomadic peoples were actively using fire in the *cerrado* and on rainforest borders 4,000–5,000 years ago, and the use of fire was widespread among most indigenous groups in Brazil before the arrival of Europeans.[47]

Periodic burning in the *cerrado*, such as that carried out by Indigenous Peoples, has been found to result in less-destructive fires and to have positive effects on biodiversity.[48] Indigenous Peoples in the *cerrado* use fire for various purposes, such as to clear pathways for ease of walking; open areas for swidden agriculture; to kill or drive away pests and snakes; eliminate wastes; attract and drive game during hunting; and stimulate grass regrowth and the flowering and fruiting of some plants.[49] Hunting with fire is a characteristic activity of many Indigenous Peoples in the *cerrado*, such as the Kayapó, Krahô, Canela, and Xavante.[50]

## Tropical rainforests

Tropical rainforests rarely burn naturally because of the low co-incidence of lightning with climatic conditions suitable to carry fire; moreover, if fire is initiated, the high moisture content in the fuels in tropical rainforests generally prevents propagation.[51] On the other hand, fire is a main tool for the large-scale conversion of tropical rainforests to agricultural land.[52] In tropical rainforests, therefore, management approaches that minimize extensive fires are likely to achieve the best outcomes for biodiversity conservation and carbon sequestration.

A global study of the tropical forest biome used forest fires as a proxy for deforestation and compared the incidence of fire in strictly protected areas, multiple-use protected areas, and indigenous-managed lands (the latter only in Latin America and the Caribbean, mainly Brazil). It found that, in Latin America and the Caribbean, multiple-use protected areas were as effective or more effective in preventing fire than strictly protected areas, but indigenous areas were almost twice as effective as any other form of protection.[53] Community-managed forest concessions in the Maya Biosphere Reserve, an area of tropical rainforest in Guatemala, have a far lower incidence of wildfire than nearby strictly protected areas and the reserve's buffer zone (see below).[54]

# Fire management agencies are seeking collaboration with traditional land managers

The predominant governmental approaches to fire management and suppression are under pressure worldwide – catastrophic fires with huge losses of property and human lives have occurred in recent years in Australia, Brazil, California, Canada, Indonesia, the Mediterranean Basin, Portugal, Russia, South Africa, and elsewhere. Fire management agencies worldwide are urgently rethinking their strategies, and some are turning to traditional land managers for help.

Traditional Knowledge is acquired by using fire in subsistence farming and land stewardship, and for religious purposes.[55] Typically, Traditional Knowledge is passed from generation to generation in each locality. For Indigenous Peoples, "the landscape will convey its need for burning based on factors such as the accumulation of dead plant materials or the decline in resource conditions. Such knowledge may be encoded in the stories of a region".[56] Western knowledge, on the other hand, is obtained from observation, experimental manipulations, and modeling using methodologies that strive to be objective.[57] Many indigenous fire systems are also interwoven with spiritual beliefs, while such beliefs are explicitly excluded from Western ways of knowing.

Western and Traditional Knowledge also share important attributes, such as verification through repetition; the use of inference and prediction; empirical observations; and recognition of pattern events.[58] Some studies have also identified a complementarity between Western and Traditional Knowledge systems in understanding human-environment relationships. This work characterizes Western Science as "broad", as a system of set principles with applicability in any given context, yet it often remains "shallow", as research of human-environment remains relatively scant in much the world´s landscapes. Traditional knowledge on the other hand, often represents a deep and intricate form of knowledge relating to the dynamics of one specific area, yet it remains "narrow", as it may not transfer easily from one place to another.[59] The two systems therefore present opportunities for synergies.

Drawing on both Traditional and Western knowledge can more fully inform fire management to reduce fire risk and hazard, reintroduce fire, and maintain cultural landscapes.[60] Below, three examples show that emerging collaborations between fire management agencies and Indigenous Peoples and local communities can have a wide range of benefits, including a reduction in catastrophic wildfire.

## The Yurok Tribe in partnership with CALFIRE in California, USA

With wildfire threats likely to increase in the western United States as the climate changes, a new paradigm for fire management is starting to emerge from collaboration between Native American tribes, nongovernmental organizations, and government agencies.

The Yurok indigenous territory in northern California encompasses more than 160,000 hectares, including about 64 km of the Pacific coast and 86 km of the Klamath River watershed to the confluence of the Klamath and Trinity rivers.[61] Culturally, the Yurok people are known as great fishers, eelers, basket weavers, canoe makers, storytellers, singers, dancers, healers, and strong medicine people.[62]

Many aspects of the Yurok culture are fire-dependent. For example, the Yurok use fire to manage hazel, the main material used in basket-making: when hazel is burned in early spring or fall it grows back straight, long, and sufficiently supple for basket weaving. Controlled burns also help ensure supplies of medicinal plants and foods such as huckleberries and acorns; facilitate forest access for the collection of acorns; attract wildlife; and protect villages, houses, and spiritual areas from larger fires by clearing nearby areas.

The United States Forest Service and local Yurok institutions, supported by The Nature Conservancy, an environmental nongovernmental organization, have jointly conducted training in controlled burns on the Yurok Tribe's ancestral reservation. The Yurok prescribed fire training exchange (known as Yurok TREX), which began in 2014, involves Yurok tribal members and staff from state and federal fire management agencies combining and adding to their ecological and fire knowledge. In 2017, for the first time, the California Department of Forestry and Fire Protection (CALFIRE) participated in a controlled burn along a state highway as part of Yurok TREX. [63]

Two workshops were convened in 2012 and 2014 with the aim of engaging a diverse community of tribal and nontribal managers, scientists, and students on the challenges and solutions associated with combining traditional and Western approaches to wildland fire, fuels, and natural and cultural resource management.[64] Most North American tribes have traditional knowledge about how fire affects ecosystems, habitats, and resources, and many once used fire to improve the quantity, quality, and functionality of valued resources and habitats. Many tribal communities want to apply their traditional knowledge and cultural burning with contemporary fire and resource management, but a range of factors limits the application of this knowledge today.[65]

The process of developing joint approaches will undoubtedly take time. According to participants in the 2012 and 2014 workshops mentioned above, the crucial element for successful cross-jurisdictional fire and fuel management is building and improving communication and relationships between tribes and federal agencies, between disciplines within agencies, and between tribal land managers and tribal members.[66] The first Yurok TREX started with a journey by boat along the Klamath River, during which resource managers from the tribe pointed out different vegetation communities, discussed observed changes since the removal of fire from the landscape, and identified villages sites and places where traditional dances and other ceremonies still occur.[67]

Some tribal members have attested to significant benefits, helping unite government agencies, and NGOs, together towards a common goal of eliminating arson and restoring traditional land management practices [68].

> "Cultural fire burns [are to provide] cultural resources and food security. So we're burning for hazel and bear grass for our weavers, huckleberries, acorns, various medicinal plants, herbal remedies, things that we have used from time immemorial, and it's really nice to go back into the areas that

> we have burned and see the wildflowers coming back and the plants, the hazel sticks. The girls are coming out with bundles this big, you know, and smiling just as big. Being able to gather again and walk through an area without getting hung up or lost. We've been seeing more animals – more bears, more deer, bobcats – we've photographed a few mountain lions. …
>
> "In our units we have a study going on where we have some grad students that come out from Stanford and basically photograph the hazel from the time it's burnt until the time it has sprouted out. They are studying if we're burning too hot, if we're not burning hot enough, and what we can do to make our hazel stands better … Here we are today working with all these various agencies – Humboldt County Air Quality, CALFIRE, burning agencies from all over the state, actually. So it's been a long road, it's been hard occasionally, but it's very worth it. It's nice to see where we've come from, just this small grassroots group, to what we are now. Look at us out here – we're burning, we're working together, everybody's collaborating, it's a really nice feeling …"[69]

This progress has been an important, although tentative, first step in moving towards deeper exchange between the USFS institutions and tribal authorities. The expansion of such programs could offer opportunities for progress, yet challenges remain, particularly related to the power imbalances between local tribes and US government agencies.[70]

## Community-managed forest concessions in Guatemala

The Maya Biosphere Reserve, in the Petén region of Guatemala, covers 2.1 million hectares of lowland and hilly tropical rainforest, forming part of the broader Mayan rainforest, which is one of the largest contiguous expanses of tropical rainforest north of the Amazon. The Reserve has three zones: a core zone, a multiple-use zone, and a buffer zone. In the multiple-use zone, twelve community organizations and two private industrial firms were granted concessions for the harvesting of timber and non-timber forest products in the late 1990s and early 2000s. The community concessions (now numbering nine) cover about 400,000 hectares and the industrial concessions about 132,000 hectares.

The Maya Biosphere Reserve was established in 1990 in response to widespread deforestation in the region – although deforestation continued as illegal loggers and cattle ranchers exploited the lack of effective government presence to protect the reserve. Local communities, comprising both indigenous and non-indigenous people, united to create an association to represent the interests of communities dependent for their livelihoods on managing and protecting the forests. After a long negotiation process with state agencies, the association won rights to forest concessions for renewable 25-year periods. Today, the community forest concessions are managed by collective decision-making organizations made up of community representatives.

Traditional knowledge of controlled burning for agriculture is found mainly among the *Peten* forest communities,[71] which, before the establishment of the concession model, made their living mainly from

the harvest of non-timber products such as resins, leaves, and spices. They also farmed using a form of swidden agriculture called *milpa*, an agricultural system involving the intercropping of corn and beans in rotational cycles with tree fallows within the forest, facilitated by burning.

The extent and severity of forest fires in Petén during the dry season from January to May 2017 attracted national and international attention. An analysis of two sets of satellite data from that period found that community concessions were by far the most effective management regime in reducing landscape fires, outperforming the rest of the Maya Biosphere Reserve.[72] The fire incidence rate inside the community concessions was over 28 times lower than the high-conservation value core zone, and 31 times lower than the incidence rate found in the buffer zone. Maps generated in the study illustrate the decisive role of the community concessions, which appear as the last block of continuous forest, surrounded by fires in the rest of Petén. Forthcoming research shows that similar results prevailed in the MBR in 2018, as well as over the past decade.[73]

The effectiveness of fire control and prevention is the result of significant cooperation and coordination. The communities have established formal interinstitutional arrangements to organize themselves around fire prevention. They have developed joint fire prevention plans; cleared and maintain firebreaks along concession boundaries; conducted regular patrols of firebreaks; constructed watch towers; used drones to monitor fire threats; and trained and deployed youth in fire brigades, which operate both within and outside the forest concessions. The concession system has required modification of the traditional burning system, with special zones – agreed by communities – for *milpa* within concession areas. Nevertheless, traditional knowledge continues to be applied, for example, in the seasonal and daily timing of burns and the use of firebreaks to prevent fires from spreading beyond the *milpa* plots.

The forest communities themselves budgeted a total of USD 419,000 for forest-fire control and prevention in 2017 (and slightly more in 2018) to conduct around 1,000 patrol missions. They established more than 200 campsites for surveillance and control and planned the maintenance of 453 km of fire breaks (533 km in 2018) throughout their forest concession areas.

One of the keys to success has been cooperation, both between communities and between communities and government agencies. Inter-community collaborations include the rotation of patrols along shared boundaries between concessions and the sharing of resources and information. Recognizing the lack of government capacity to prevent fires in neighboring national park areas, the communities have also allocated their own resources to protect those borders. Governance in this part of the Maya Biosphere Reserve is stronger because of this interconnection between communities, which has had impacts beyond the limits of the concessions themselves.[74]

The relationship between community concessions and governmental authorities, in particular Guatemala's National Council of Protected Areas (CONAP), has also been important. Community leaders cite CONAP's evaluation process as important for helping ensure quality in the development and implementation of community fire management plans, as well as joint patrols and checkpoints. Community patrols use hand-held global positioning systems to locate and report fires detected in or near concessions; CONAP, in turn, informs communities of fires detected by its satellite monitoring system. The community brigades perform the bulk of the firefighting.

Cooperation is not always smooth. Some community members have indicated dissatisfaction with the relationship with CONAP, such as its ongoing requests for community resources to support fire management outside concessions because of CONAP´s own lack of resources.

For its part, CONAP has come to understand the crucial role of communities in fire management and the importance of collaboration with them. When the country's new fire management campaign was launched in 2017, the government made special mention of the role of community participation in fire and forest management, indicating that strategic alliances between the government and communities were helping ensure conservation and economic development:

> *"I would like to highlight the community participation, the participation that the People have had in the political history of the country. After the Peace Accords were signed in 1996, the agreement for granting forest concessions in the Maya Biosphere Reserve was implemented. In 1998, the country recorded the highest number of forest fires in the country, which to date has not been repeated. Yet it was beginning at that time that the forest concessions were granted within the Multiple Use Zone, and the fires have since decreased within that area. This is, therefore, clear proof that strategic alliances between the government and communities not only ensure conservation through forest management, but also protect our wildlife and represent sources of economic development for our People."*[75]

Overall, the recognition of community rights in the MBR has been the foundation for a governance system that promotes cooperation and the long-term valuation of resources.[76] Despite their success, however, these communities are facing increasing uncertainty as their concession contracts are set to expire within a few years. Large scale tourism, oil and agroindustry interests have all made proposals that threaten the renewal of the concessions. The future of the Mayan forest in Guatemala, therefore, likely hinges on ensuring the long-term rights of these communities.

## Indigenous Peoples in Brazil are key partners with government in new fire management approaches in the *cerrado*

Until recently, the official fire policy in most Brazilian landscapes was "zero fire", due at least partly to a misunderstanding in government institutions about the role of fire in the *cerrado*.[77] Fire prohibition and the criminalization of traditional communities have also been used to legitimate the expansion of agribusinesses that do not rely on fire use.[78] Nevertheless, zero-fire policies in protected areas in the *cerrado* have commonly led to large wildfires.[79]

As evidence has grown that fire is an integral part of many ecosystems, Brazilian scientists and decision-makers have started to question the zero-fire paradigm and to recognize that fire-suppression policies in protected areas in the *cerrado* have been ineffective or counterproductive.[80] Researchers have convened workshops in Brazil and Venezuela (where participatory approaches to fire management with traditional knowledge are also being developed) involving local indigenous and traditional community

representatives, scientists, environmental managers, and government officials. These multi-stakeholder workshops have contributed to the development of a new national fire management policy in Brazil that explicitly includes traditional fire practices. [81]

Official approval of indigenous fire management practices in Brazil is due to three recent changes: legal recognition of traditional burning practices in the new national Forest Code; the creation of a program for the control of forest fires on indigenous lands (the Ibama/Prevfogo Federal Brigades Program), which creates indigenous fire brigades in communities; and the training of government technicians in integrated fire management supported by the governments of Brazil and Germany. [82]

The beginnings of a new approach to fire policy can be traced to a project that attempted to introduce a zero-fire rule to the Paresi Indigenous people in Mato Grosso in 2007. Paresi elders rejected the attempt, instead stressing the importance of fire management for the conservation of the *cerrado*. In response, the project investigated the objectives, principles, and methods of traditional practices, leading to a joint fire planning exercise with the indigenous community. The main characteristic of the fire management plan that emerged was that it was based on the ecology of plants and animals important to the community, such as crops, sacred and game animals. Nevertheless, the field results in 2007 were unsatisfactory, partly because of a loss of fire culture among younger people in the community and a lack of remuneration for the work to be carried out. [83]

In 2014, the same project commenced a pilot program in integrated fire management in three protected areas in the *cerrado*, adapting the methodology developed with the Paresi People to introduce community-based integrated fire management on Xerente indigenous lands. This time, the effort was successful. [84] The strategy of consulting elders and chiefs on the traditional use of fire, and incorporating this with government guidance on forest fire control techniques, was important in obtaining community support for the program. The fire brigades, comprising Xerente people, quickly learned "old" and "new" fire management techniques, including the use of satellite images via mobile phones in planning where to carry out controlled burns. [85]

Similar processes have recently been implemented elsewhere in the *cerrado* with the Javaé and Karajá Indigenous Peoples (in Araguaia, Tocantins) and the Krahô peoples (in Kraolândia, Tocantins).[86]

There are indications that the new strategy is working. In the first three years of the introduction of the new integrated fire management regime in the three protected areas, there was a 40–57 percent reduction in late-dry-season fires (which are generally hotter and more dangerous than early-dry-season fires). Dialogue between researchers, managers, and local communities has improved, helping create "fire management learning communities". [87]

Fire management agencies and professional fire practitioners in Brazil still have much to learn about the ways in which Indigenous Peoples and local communities use fire, and about how to pursue deeply collaborative approaches. To be successful, these methods must go beyond the hiring of local people as firefighters to include a deeper level of knowledge exchange. This process is incipient, yet the shift from a sole focus fire suppression, towards a more integrated approach, represents a major step forward.[88]

# Obstacles – and opportunities for progress

Integrating Traditional Fire Knowledge held by local communities and Indigenous Peoples into fire management policy could reduce the potential for catastrophic wildfires in a range of biomes and landscapes. Indigenous Peoples and local communities have a fine-scale culturally and ecologically deep understanding of their landscapes and are open to collaboration. They are present in landscapes all day, every day, and thus have a heightened situational awareness of likely fire behavior and impacts.

Evidence is accumulating that working with Indigenous Peoples and local communities can be an effective – and cost-effective – means for mitigating wildfire and, in some cases, a key part of averting catastrophic fire events. Nevertheless, obstacles exist to the widespread uptake of collaborative approaches. The three examples given in this report show that a range of social and ecological factors need to be addressed to enable Indigenous Peoples and local communities to maintain their Traditional Fire Knowledge and practices. Our study provides four recommendations for building on the progress of these initiatives.

- Recommendation 1: Address legal and political constraints on the land tenure, access, and stewardship of Indigenous Peoples and local communities to empower them to maintain their Traditional Fire Knowledge and practices and enable fully collaborative approaches to fire management.

Consolidating the land and resource tenure security of local communities and indigenous peoples has demonstrated its potential to contribute towards enhancing livelihoods and the sustainable management of forests and forested ecosystems. The exercise of fire knowledge is a key expression of community rights in practice, where traditional communities can contribute to sustainable land management, and to provide cultural reproduction rooted in local ecosystems. Secure land tenure is a key condition for ensuring effective partnership with these communities into the future.

- Recommendation 2: Strengthen the next generation of fire-knowledge bearers by helping young members of indigenous and local communities to apply the fire wisdom and practices of their ancestors and by supporting training intercultural fire management.

Traditional communities across the world face tremendous threats to their way of life, as land grabbing, cultural erosion and climate change, among others, force communities into new dilemmas in order to cope with these pressures. Maintaining Traditional Knowledge is a challenge in these circumstances. Efforts to ensure the resilience of these Peoples encompass a panoply of innovative strategies, including proposals for securing tenure, the development of indigenous "life plans", or community forestry. Initiatives to protect or revive Traditional Fire Knowledge amongst new generations could be more explicitly supported as a part of these locally-led strategies.

- Recommendation 3: In scientific research, value the traditional knowledge embedded in indigenous oral histories and evaluate the outcomes of traditional fire practices.

Scientific research with indigenous people incorporating Traditional Knowledge can often be the critical turning-point for broader recognition of such systems. One promising intercultural fire processes in Venezuela emerged only after Western research methods identified the landscape utility and logic of indigenous management that had hitherto been misunderstood.[89] Such research can act as a key "bridge" in ensuring synergies between the universal applicability of Western science, with the specific and local "depth" of Traditional Knowledge. This can also be important for addressing entrenched perspectives among governmental practitioners, many of whom may value Traditional Knowledge when it supports or supplements scientific evidence but dismissing it as myth when it appears to challenge scientific "truths".[90]

- Recommendation 4: Build intercultural fire management partnerships involving indigenous and local communities, professional practitioners, and researchers that enable the sharing of knowledge, wisdom, and toil and are based on trust, mutual respect, and honest communication.

The examples highlighted in this report demonstrate that important gains can be made in mitigating wildfires and climate change through more effective partnerships between governments and traditional communities. Such processes must grapple with major challenges for overcoming mistrust, deep seated professional and local conceptions of the validity of other knowledge systems, and the changing dynamics of wildfire. Yet the increasing severity of wildfire and catastrophic fires has already forged some of these partnerships, quite literally, around the fires exacerbated by climate change. The cases highlighted here point the way forward for amplifying the potential of such partnerships.

# Endnote

[1] BBC News. 2018. Greece wildfires: search for missing family members after 80 people die. https://www.bbc.com/news/world-europe-44948173; VOA News. 2018. Death toll in Greek fires rises to 91, 25 missing. Voice of America, 29 July. www.voanews.com/a/death-toll-in-greek-fires-rises-to-91-25-missing/4505396.html

[2] Smith-Spark, L, Smith, R and Mezzofiore, G 2018. Evacuations ordered in Sweden as fires rage as far north as Arctic Circle. CNN, 24 July. https://edition.cnn.com/2018/07/19/europe/sweden-forest-fires-wxc-intl/index.html

[3] National Interagency Fire Center. 2018. July 25, 2018. www.nifc.gov/fireInfo/nfn.htm

[4] Voiland, A. 2018. Forest fires in Russia's Far East. NASA Earth Observatory, 4 April 2018. https://earthobservatory.nasa.gov/images/91969/forest-fires-in-russias-far-east

[5] Intergovernmental Panel on Climate Change 2014. *Climate change 2014: synthesis report. Contribution of working groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. Geneva, Switzerland.

[6] McDermid, C 2018. California today: experts on fire season 2018 discuss the 'new normal'. *The New York Times*, 23 May 2018. www.nytimes.com/2018/05/23/us/california-today-fire-season-2018.html

[7] Quoted in Irfan, U 2017. It's official: this was California's worst fire season ever. MSN News, 1 December 2017. www.msn.com/en-

us/news/other/its-official-this-was-californias-worst-fire-season-ever/ar-AAtmNVC

[8] Hoover, K 2017. Wildfire Management Funding: Background, Issues, and FY2018 Appropriations. Congressional Research Service. https://fas.org/sgp/crs/misc/R45005.pdf

[9] Quoted in Mason, M and Rubin, J 2018. Wildfire in Yolo County grows to 32,500 acres, forcing evacuations. *Los Angeles Times*, 1 July.

[10] Jolly, WM, Cochrane, MA, Freeborn, PH, Holden, ZA, Brown, TJ, Williamson, GJ, and Bowman, DMJS 2015. Climate-induced variations in global wildfire danger from 1979 to 2013. *Nature Communications*, 6: 7537. The length of the fire season decreased on 10.7 percent of the global vegetated area (12.5 million $km^2$).

[11] Not including Antarctica.

[12] Jolly et al. 2015, as cited above.

[13] Dennison, PE, Brewer, SC, Arnold, JD, and Moritz, MA 2014. Large wildfire trends in the western United States, 1984–2011. *Geophysical Research Letters*, 41: 2928–2933.

[14] Cleetus, R and Mulik, K 2014. *Playing with fire: how climate change and development patterns are contributing to the soaring costs of western wildfires*. Union of Concerned Scientists.

[15] Lannom, KO, Tinkham, WT, Smith, AMS, Abatzoglou, J, Newingham, BA, Hall, TE, Morgan, P, Strand, EK, Paveglio, TB, Anderson, JW, and Sparks, AM 2014. Defining extreme wildland fires using geospatial and ancillary metrics. *International Journal of Wildland Fire*, 2014, 23: 322–337.

[16] Specifically, increases in temperature and vapor pressure deficit arising from human-caused climate change. Vapor pressure deficit is the difference between the amount of moisture in the air and how much moisture the air can hold when it is saturated. It is, therefore, a measure of humidity. Vegetative litter (which forms part of the fuel in a wildfire) will dry out more quickly and more completely when the vapour pressure deficit is high.

[17] Abatzoglou, JT and Park Williams, A 2016. Impact of anthropogenic climate change on wildfire across western US forests. *PNAS*, 113(42): 11770–11775.

[18] Westerling, AL 2016. Increasing western US forest fire activity: sensitivity to changes in the timing of spring. *Philosophical Transactions of the Royal Society B*, 371: 20150178.

[19] Teague, B, Macleod, R, and Pascoe, S 2010a. 2009 Victorian Bushfires Royal Commission. Volume 1: The fires and the fire-related deaths. Melbourne, Australia: Parliament of Victoria.

[20] Teague, B, Macleod, R, and Pascoe, S 2010b. 2009 Victorian Bushfires Royal Commission. Summary. Melbourne, Australia: Parliament of Victoria.

21.Teague et al. (2010a), as cited above.

[22] Yongqiang Liu, Stanturf, J, and Goodrick, S 2009. Trends in global wildfire potential in a changing climate. *Forest Ecology and Management*, 259: 685–697.

[23] Bowman, DMJS, Williamson, GJ, Abatzoglou, JT, Kolden, CA, Cochrane, MA, and Smith, AMS 2017. Human exposure and sensitivity to globally extreme wildfire events. *Nature Ecology & Evolution*, 1: 0058.

[24] Bowman, DMJS, Balch, J, Artaxo, P, Bond, WJ, Cochrane, MA, D'Antonio, CM, DeFries, R, Johnston, FH, Keeley, JE, Krawchuk, MA, Kull, CA, Mack, M, Moritz, MA, Pyne, S, Roos, CI, Scott, AC, Sodhi, NS, and Swetnam, TW 2011. The human dimension of fire regimes on Earth. *Journal of Biogeography*, 38: 2223–2236.

[25] Schoennagel, T, Balch, JK, Brenkert-Smith, H, Dennison, PE, Harvey, BJ, Krawchuk, MA, Mietkiewicz, N, Morgan, P, Moritz, MA, Rasker, R, Turner, MG, and Whitlock, C. 2017. Adapt to more wildfire

in wetern North American forests as climate changes. *PNAS Early Edition*, 1–9.

[26] Schoennagel et al. (2017), as cited above.

[27] Williams, J. 2013. Exploring the onset of high-impact mega-fires through a forest land management prism. *Forest Ecology and Management*, 294: 4–10.

[28] Bowman, DMJS, Williamson, GJ, Abatzoglou, JT, Kolden, CA, Cochrane, MA, and Smith, AMS 2017. Human exposure and sensitivity to globally extreme wildfire events. *Nature Ecology & Evolution*, 1: 0058.

[29] Stephens, SL, McIver, JD, Boerner, REJ, Fettig, CJ, Fontaine, JB, Hartsough, BR, Kennedy, P, and Schwilk, DW 2012. The effects of forest fuel-reduction treatments in the United States. *BioScience*, 62(6): 549–560.

[30] Tauli-Corpuz, V, Alcorn, J, and Molnar, A 2018. Cornered by protected areas. Brief. Washington, DC, Rights and Resources Initiative. www.corneredbypas.com/brief

[31] Alden Wily, L 2011. *The tragedy of public lands: the fate of the commons under global commercial pressure.* Rome: International Land Coalition.

[32] Huffman, MR 2013. The many elements of traditional fire knowledge: synthesis, classification, and aids to cross-cultural problem solving in fire-dependent systems around the world. *Ecology and Society*, 18(4): 3.

[33] Huffman (2013), as cited above.

[34] Pyrogreography is "an integrative, multidisciplinary perspective of landscape fire, its ecological effects, and its relationships with human societies" (Bowman and Murphy, 2011).

[35] Huffman (2013), as cited above.

[36] Huntsinger, L and Mccaffrey, S 1995. A forest for the trees: forest management and the Yurok environment, 1850–1994. *American Indian Culture and Research Journal*, 19(4): 155–192, drawing on testimonies by "reservation residents and a variety of researchers".

[37] Welch, JR, Brondízio, ES, Hetrick, SS, and Coimbra Jr, CAE 2013. Indigenous burning as conservation practice: neotropical savanna recovery amid agribusiness deforestation in central Brazil. *PLOS ONE*, 8(12): e81226.

[38] Pivello, VR 2011. The use of fire in the cerrado and Amazonian rainforests of Brazil: past and present. *Fire Ecology*, 7(1): 24–39.

[39] E.g. Pretty, J, Adams, B, Berkes, F, Ferreira de Athayde, S, Dudley, N, Hunn, E, Maffi, L, Milton, K, Rapport, D, Robbins, P et al. (2009). The intersections of biological diversity and cultural diversity: towards integration. Conservation and Society, 7(2): 100–112.
www.jstor.org/stable/26392968

Barismantov, J. y Antezana, J. (2012). Forest Cover Change and Land Tenure Change in Mexico's Avocado Region: Is Community Forestry Related to Reduced Deforestation for High Value Crops? Applied Geography 32: 844–53.

Barismantov, J. y Kendall, J. (2012). Community Forestry, Common Property and Deforestation in Eight Mexican States. The Journal of Environment and Development 21(4): 414–37.

Bonilla-Moheno, M., Redo, D., Aide, T. M., Clark, M., y Grau, H.R. (2013). Vegetation Change and Land Tenure in Mexico: A Country-wide Analysis. Land Use Policy 30: 355–64.

Davis, A. et al 2015. Rights-based Governance: Experiences of Territorial Authorities in Mesoamerica. San Salvador, Fundacion PRISMA.

Davis, A. (2014). De la degradación y conflicto a la gestión territorial: el reconocimiento de derechos comunitarios en Gualaco y Guata, Honduras. Fundación PRISMA. San Salvador.

Duran, E. et al. (2005). Land-use Cover Change in Community based Forest Management Regions

and Protected Areas in Mexico. In *The Community Forests of Mexico*, 215–40. D. Bray, L. Merino-Pérez y D. Barry (eds). Austin, TX: University of Texas Press.

DiGiano, M. et al. (2013). Changing Landscapes for Forest Commons: Linking Land Tenure with Forest Cover Change Following Mexico's 1992 Agrarian Counter-Reforms. *Human Ecology*, *41*(5), 707–723. https://doi.org/10.1007/s10745-013-9581-0

Ellis, E. A., & Porter-Bolland, L. (2008). Is community-based forest management more effective than protected areas?: A comparison of land use/land cover change in two neighboring study areas of the Central Yucatan Peninsula, Mexico. *Forest Ecology and Management*, *256*(11), 1971–1983. https://doi.org/10.1016/j.foreco.2008.07.036

Barsimantov, J., & Kendall, J. (2012). Community Forestry, Common Property, and Deforestation in Eight Mexican States. *The Journal of Environment & Development*, *21*(4), 414–437. https://doi.org/10.1177/1070496512447249

Hayes, T. (2007). Controlling Agricultural Expansion in the Mosquitia: Does Tenure Matter? Human Ecology 35(6): 733–47.

Hughell, D., & Butterfeld, R. (2008). *Impact of FSC Certifcation on Deforestation and the Incidence of Wildfres in the Maya Biosphere Reserve*. Rainforest Alliance New York, NY, USA. Retrieved from http://dk.fsc.org/preview.impacts-of-fsc-in-the-guatemala-maya-biosphere-reserve.a-240.pdf

Nittler, J., & Tschinkel, H. (2005). *Community forest management in the Maya Biosphere Reserve of Guatemala: Protection through profts*. USAID. Retrieved from http://pdf.usaid.gov/pdf_docs/PNADO388.pdf

Radachowsky, J. et al. (2012). Forest concessions in the Maya Biosphere Reserve, Guatemala: A decade later. *Forest Ecology and Management*, *268*, 18–28. https://doi.org/10.1016/j.foreco.2011.08.043

Nelson, A. y Chomitz, K. M. (2009). Protected Area Effectiveness in Reducing Tropical Deforestation. A Global Analysis of the Impact of Protection Status. Evaluation Brief 7. Independent Evaluation Group World Bank.

Bray, D. B.et al.(2008). Tropical Deforestation, Community Forests, and Protected Areas in the Maya Forest. *Ecology and Society*, *13*(2), 56.

Hayes, T. M. (2007). Does Tenure Matter? A Comparative Analysis of Agricultural Expansion in the Mosquitia Forest Corridor. *Human Ecology*, *35*(6), 733–747. Vergara-Asenjo, G., and C.J. Potvin. 2014. Forest protection and tenure status: the key role of indigenous peoples and protected areas in Panama. Global Environmental Change (28) 205-215.

Min-Venditti, A. et al. (2017) What policies improve forest cover? A systematic review of research from Mesoamerica. *Global Environmental Change* (47) 21-27.

[40] The Rights and Resources Initiative (2016) Toward A Global Baseline of Carbon Storage in Collective Lands: An updated analysis of indigenous peoples´and local communities´contributions to climate change mitigation. RRI, Woods Hole Research Center and Landmark. Washington, D.C.

[41] E.g. Chhatre, Ashwini and Arun Agrawal. 2009. Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. PNAS, 106 (42) 17667–17670. https://doi.org/10.1073/pnas.0905308106

[42] Crawford, JN, Mensing, SA, Lake, FK, and Zimmerman, SRH 2015. Late Holocene fire and vegetation reconstruction from the western Klamath Mountains, California, USA: a multidisciplinary approach for examining potential human land-use impacts. *The Holocene*, 25(8): 1341–1357; Huntsinger and Mccaffrey (1995), as cited above.

[43] Huntsinger and Mccaffrey (1995), as cited above; see also Halpern, A.A. 2016. *Prescribed fire and tanoak (*Notholithocarpus densiflorus*) associated cultural plant resources of the Karuk and Yurok Peoples of California*. Doctoral dissertation, University of California Berkeley.

[44] Crawford et al. (2015), as cited above.

[45] UNU 2015. *The global potential of indigenous fire management: findings of the regional feasibility assessments.* United Nations University (UNU).

[46] Welch et al. (2013), as cited above.

[47] Pivello (2011), as cited above.

[48] Welch et al. (2013), as cited above.

[49] Pivello (2011), as cited above.

[50] Welch et al. (2013), as cited above.

[51] Bowman et al. (2011), as cited above.

Nelson, A and Chomitz, MK 2011. Effectiveness of strict vs. multiple use protected areas in reducing tropical forest fires: a global analysis using matching methods. *PLoS ONE*, 6(8): e22722.

[53] Nelson and Chomitz (2011), as cited above.

[54] Davis, A and Sauls, L 2017. *Evaluating forest fire control and prevention effectiveness in the Maya Biosphere Reserve*. Asociación de Comunidades Forestales de Petén and PRISMA Foundation.

[55] Lake, FK, Wright, V, Morgan, P, McFadzen, M, McWethy, D, and Stevens-Rumann, C 2017. Returning fire to the land: celebrating traditional knowledge and fire. *Journal of Forestry*, 115(5): 343–353.

[56] Eriksen, C and Hankins, DL 2014. Colonisation and fire: gendered dimensions of indigenous fire knowledge retention and revival. In A Coles, L Gray and J Momsen (eds), *The Routledge Handbook of Gender and Development*, pp. 129–137. New York, United States: Routledge.

[57] Lake et al. (2017), as cited above.

[58] Nicholas, G 2018. It's taken thousands of years, but Western science is finally catching up to Traditional Knowledge. *The Conversation*, 15 February. https://theconversation.com/its-taken-thousands-of-years-but-western-science-is-finally-catching-up-to-traditional-knowledge-90291

[59] Perfecto, I., Vandermeer, J. H., & Wright, A. L. (2009). *Nature's matrix: Linking agriculture, conservation and food sovereignty*. London: Earthscan.

[60] Lake et al. (2017), as cited above.

[61] Huntsinger and Mccaffrey (1995), as cited above.

[62] Yurok Tribe. Undated. Culture. The Yurok Tribe. www.yuroktribe.org/culture

[63] Houston, W 2017. Yurok Tribe, fire agencies to conduct controlled burns. *Eureka Times-Standard*, 16 May 2017.

[64] Lake et al. (2017), as cited above.

[65] Lake et al. (2017), as cited above.

[66] Lake et al. (2017), as cited above.

[67] Fire Learning Network 2014. Yurok Prescribed Fire Training Exchange. Notes from the field, Weitchpec, California, May/June.

[68] Yurok Tribe. 2017. Elizabeth Azzuz talks about cultural fire. YouTube video. 24 May 2017. www.youtube.com/watch?v=aV5ZaIEdukI

[69] Yurok Tribe. 2017, as cited above.

[70] Mary Huffman, Director of the Indigenous Fire Burning Network, The Nature Conservancy, personal communication, 31 July 2018.

[71] In the Uaxactun, Carmelita, and AFISAP community concessions.

[72] Davis and Sauls (2017), as cited above; A. Davis, personal communication, July 2018.

[73] Monterroso I., L. Sauls, A. Davis and M. Marti (forthcoming). Incendios, turismo y dinámicas territoriales en Peten, Guatemala. Fundación PRISMA.

[74] Davis and Sauls (2017) as cited above.

[75] Public statement by Elder Figueroa, Executive Secretary of the National Council for Protected Areas of Guatemala, 16 June 2017, at the launch of the "Zero Fires" Campaign. Guatemala City, Guatemala.

[76] Davis and Sauls (2017), as cited above.

[77] Durigan, G and Ratter, JA 2016. The need for a consistent policy for cerrado conservation. *Journal of Applied Ecology*, 53: 11–15.

[78] Eloy, L, Bilbao, BA, Mistry, J, and Schmidt, IB 2018. Forest fire suppression to fire management: advances and resistances to changes in fire policy in the savannas of Brazil and Venezuela. *The Geographical Journal*, 2018; 00: 1–13.

[79] Mistry, J, Schmidt, IB, Eloy, L, and Bilbao, B 2018. New perspectives in fire management in South American savannas: the importance of intercultural governance. *Ambio*.

[80] Eloy et al. (2018), as cited above.

[81] Mistry et al. (2018), as cited above.

[82] Falleiro, RM, Santana, MT, and Berni, CR 2016. As Contribuições do manejo integrado do fogo para o controle dos incêndios florestais nas terras indígenas do Brasil. *Biodiversidade Brasileira*, 6(32): 88–105.

[83] Falleiro et al. (2016), as cited above.

[84] Falleiro et al. (2016), as cited above.

[85] Falleiro et al. (2016), as cited above.

[86] Falleiro et al. (2016), as cited above.

[87] Schmidt, IB, Moura, LC, Ferreira, MC, Eloy, L, Sampaio, AB, Dias, PA, and Berlinck, CN 2018. Fire management in the Brazilian savanna: first steps and the way forward. *Journal of Applied Ecology*, 2018: 1–8.

[88] Jay Mistry. Professor of Environmental Geography at Royal Holloway University of London, personal communication, 19 July 2018.

[89] Bibiana Bilbao. Professor at the Simon Bolivar University in Venezuela, personal communication, 31 July 2018.

[90] Nicholas (2018), as cited above.

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