2.7

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.

Introduction

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

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.

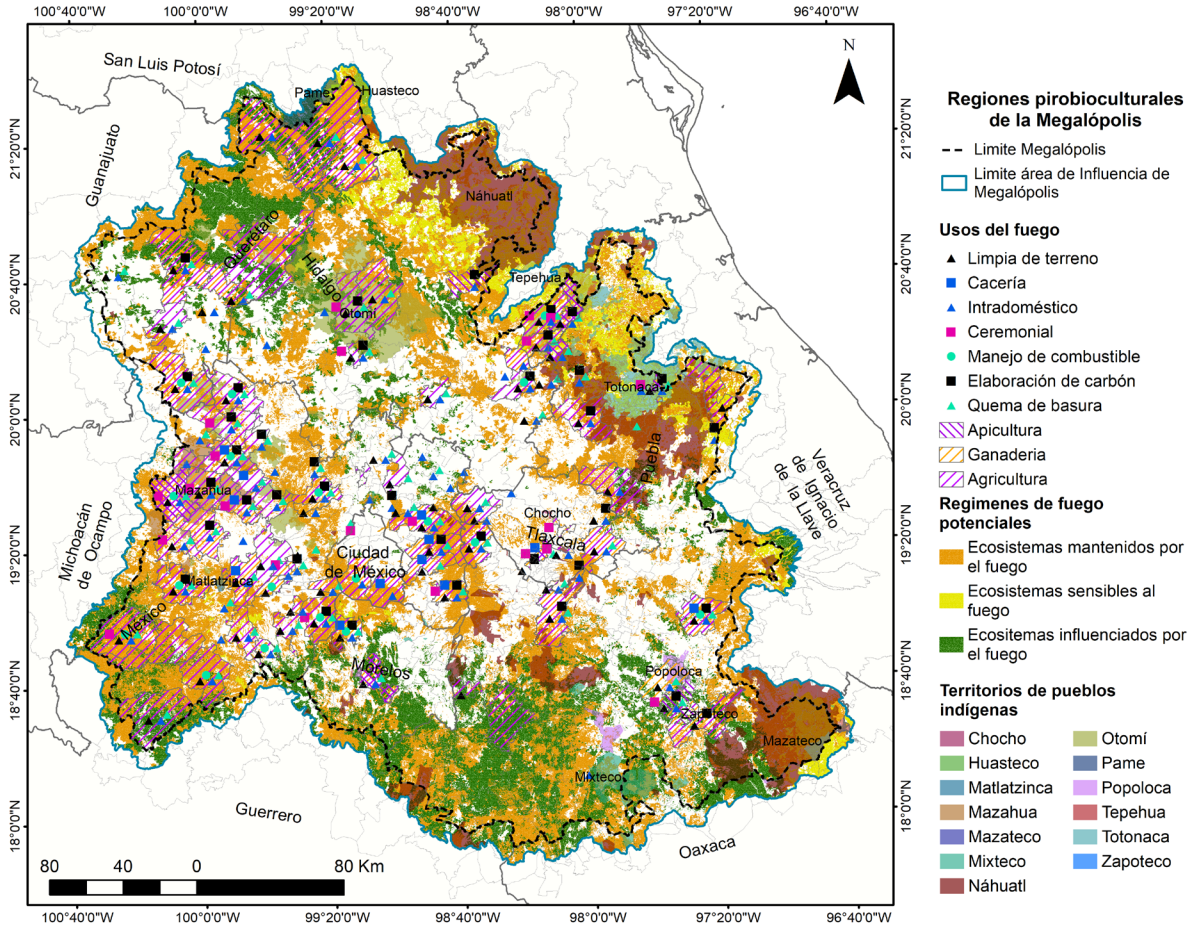

Figure 1. Pyrobiocultural map of the Megalopolis region, including relationships between vegetation and fire, uses of fire, and territories of indigenous communities. Source: UACh-CAMe (2021)

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.

Acknowledgements

This article resulted from the Diagnosis to develop the fire management strategy and programmes for the forest area of the Megalopolis, 2021–2024 project, conducted by the Autonomous University of Chapingo (UACh), under the initiative and supervision of the Megalopolis Environmental Commission (CAMe) and under the supervision of the National Forestry Commission (CONAFOR). Thanks to the CAMe Trust Fund 1490 for financial support, and to local community interviewees, and staff from the participating organizations.

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Author affiliations

Dante Arturo Rodríguez-Trejo, Professor, División de Ciencias Forestales, Universidad Autónoma Chapingo, Estado de México, Mexico (dantearturo@yahoo.com)

Laura Patricia Ponce-Calderón, Researcher, El Colegio de la Frontera Sur, Chiapas, Mexico (laponce@ecosur.edu.mx)

Hubert Tchikoué, Professor, División de Ciencias Forestales, Universidad Autónoma Chapingo, Estado de México, Mexico (tchikoue@hotmail.com)

Roberto Martínez-Domínguez, Fire management consultant, Mexico City, Mexico (roberto.martinez570607@gmail.com)

Pedro Martínez-Muñoz, Fire management consultant, BIOMASA AC, Villaflores, Chiapas, Mexico (pmtz29@hotmail.com)

Jorge Alberto Pulido-Luna, Fire management consultant, Texcoco, Estado de México, Mexico (jorgepulidoluna@gmail.com)