

# EVALUATING FOREST FIRE control and prevention effectiveness in the Maya Biosphere Reserve





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June 2017



# Index

Foreword .....	3
I. Introduction .....	5
II Effectiveness of fire prevention, monitoring and control in the Maya Biosphere Reserve .....	7
III. Historical context for understanding firefighting and fire prevention in Petén. ....	14
IV. Conclusion: models for forest governance in the Petén. ....	21
Endnotes .....	23

## FIGURES

### Figure 1

Fire incidence in the Maya Biosphere Reserve during the 2017 dry season. ....	5
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### Figure 2.

The Maya Biosphere Reserve, Petén, Guatemala.....	7
---	---

### Figure 3.

Percentage of area and of fires (MODIS C6 1 km) in each zone of the MBR. ....	8
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### Figure 4.

Forest fires based on the VIIRS 375 M product.....	11
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### Figure 5.

Fire incidence rates by zone and management type .....	12
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### Figure 6.

Efforts by community concession organizations in the MBR to prevent, manage, and control fires. ....	13
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# Foreword

In 1996, after 36 years of conflict, Guatemala signed the Peace Accords. One of the agreements stemming from these Accords, which has been successfully implemented and considered one of the most important legacies of the European Union, is the Community Forest Concession model in the Multiple Use Zone of the Maya Biosphere Reserve (MBR). This model is implemented by the Association of Community Forestry of Petén (ACOFOP), and is also known as **“Forests of Peace”**.

Today, the community-based organizations belonging to ACOFOP have 398,300 hectares of forest under their responsibility in the Multiple Use Zone of the Maya Biosphere Reserve. The joint actions of ACOFOP and the National Council of Protected Areas (CONAP), have achieved integrated forest management, sustainably using the natural resources within the areas under concession. Locally, there are different levels of organization which allow for the definition of different roles that together guarantee successful community forest governance and translate into sustainable livelihoods, fewer forest fires, fewer invasions, and more conservation.

ACOFOP is currently implementing a project called “Our Lands, Our Forests” with funds from the European Union, together with a consortium that includes Belize, Honduras, and Nicaragua. This project seeks to strengthen the operational capacities and the effective inclusion of grassroots organizations in processes of forest governance, including through the signing of the Voluntary Partnership Agreements for Forest Law Enforcement, Governance and Trade (VPA-FLEGT) and National Strategies for the Reduction of Emissions from Deforestation and Forest Degradation (REDD+). Within the framework of this project, ACOFOP has joined forces with the Regional Program of Research on Development and Environment (PRISMA) and other partners to scientifically document the effect of forest fires.

This study is a contribution of the Community Monitoring Network of ACOFOP and of PRISMA that illuminates the causes of forest fire distribution and how this understanding can help to prevent and control destructive fires in the future, using Community Forest Governance as a tool to contain these fires.

Dr. Marcedonio Cortave  
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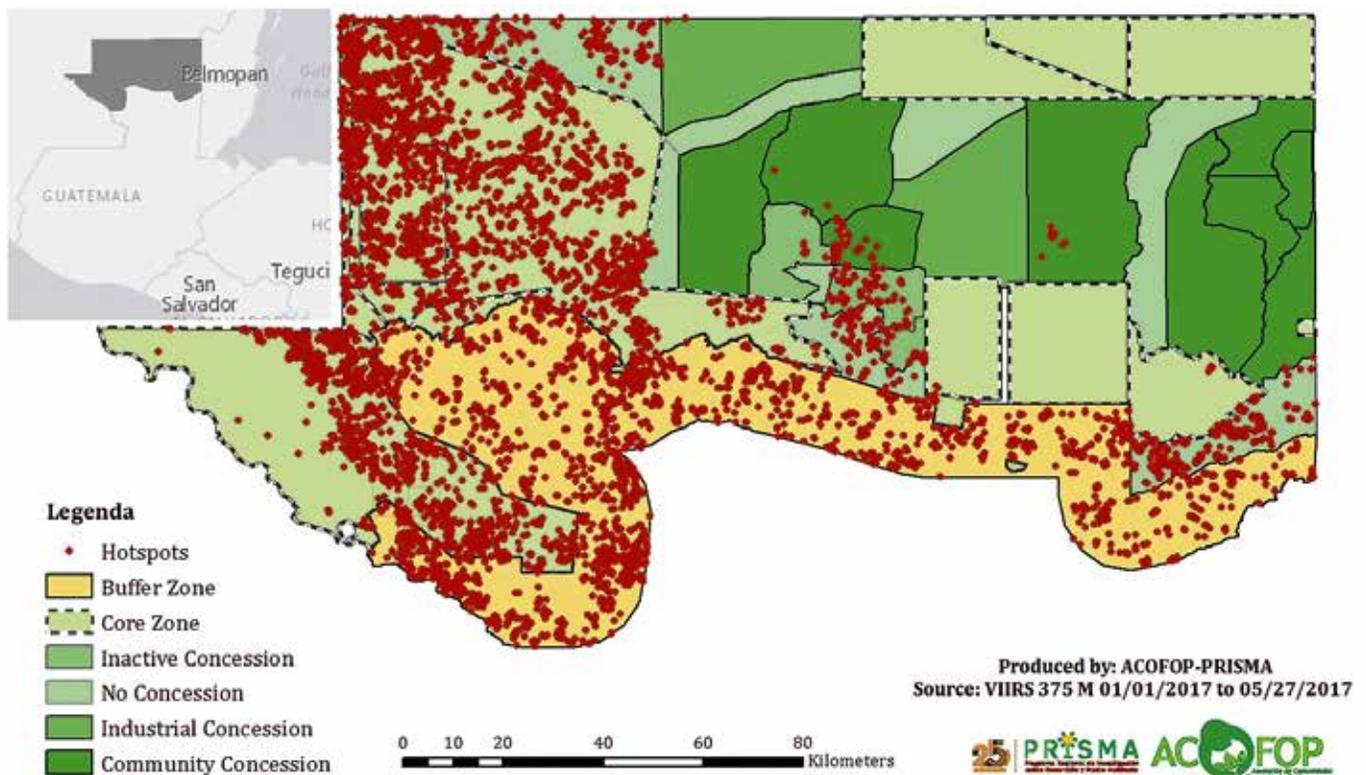
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Sign at a firebreak in the Cruce a la Colorada concession.  
Photography: Jaye Renold

# I Introduction

The extent and severity of forest fires in Petén during the 2017 dry season mobilized national and international attention amidst fears for the conservation of the natural and cultural heritage contained in the Province, especially in the Maya Biosphere Reserve (MBR). The MBR is home to several endangered and rare species, such as the jaguar and scarlet macaw, as well home to world-renowned Maya ruins. Together with the Mayan Forest of Belize and Mexico, the MBR forms part of one of the largest expanses of tropical forest north of the Amazon, providing significant ecosystem benefits, including climate change mitigation. Despite numerous media accounts depicting widespread forest fires in the Petén, a better understanding of these fires and the contribution of the community concessions is required. The project “Our Lands, Our Forests”, carried out by ACOFOP with funds from the European Union, collaborated with the PRISMA Foundation and other partners to provide a more thorough review of forest fire incidence, which review a highly varied distribution of these events (Figure 1).<sup>1</sup>

## Fires Detected in the MBR 2017



**Figure 1.**

*Fire incidence in the Maya Biosphere Reserve during the 2017 dry season. Each red dot indicates a vegetation fire, based on satellite detection of an anomalous hotspot. The darker green areas are forest concessions. From visual inspection, the fires seem strongly concentrated in the Core Zone (national parks) and Buffer Zone, especially toward the western edges of the MBR. Data source: MODIS C6 (FIRMS).*



Surveillance and control at an AFISAP firebreak.  
Photography: Paul Redman

The analysis of the 2017 vegetation fires in the MBR presented here finds that community concession organizations were more effective than strict protected areas in preventing fires in forested areas. These findings show that the concerted efforts of these communities to prevent, monitor, and control fires in their territories have made them more effective for combating the forest fires that increasingly threaten the vast biological, cultural and social reserves of the region. The results of this study underscore the urgency of renewing the community concessions, which are soon approaching their expiration. The increasing uncertainty of the rights of these communities to their lands is already threatening this model of forest management that has outperformed the strict protected area model in the MBR in avoiding deforestation and forest fires.<sup>2</sup>



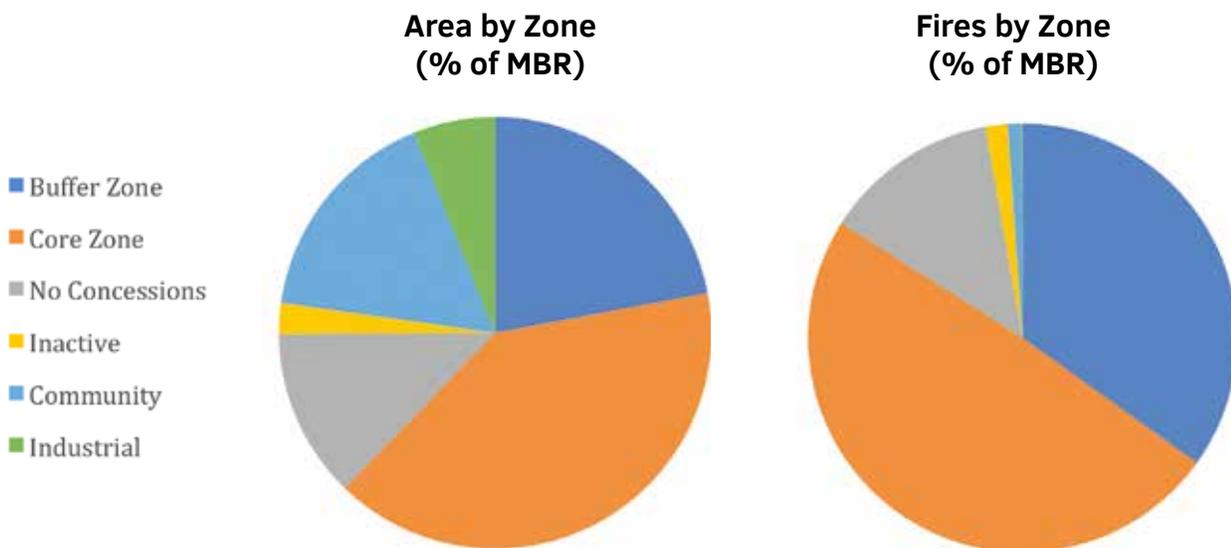
Demonstration use of drones for surveillance and control, Uaxactun. Photography: Rainforest Foundation US.



The Fire Information for Resource Management System (FIRMS) at the United States National Aeronautics and Space Administration (NASA) provides active hotspot data from the MODIS C6 1 km and VIIRS 375 M satellite products.<sup>4</sup> This analysis uses both MODIS and VIIRS data to characterize the spatial distribution of hotspots, or active fires, from January 1 to May 27, 2017.<sup>5</sup> Combining these datasets with the map of the MBR, including the different management units within it, produces a map of the number of hotspots per management area for the MBR.<sup>6</sup> Calculating the number of hotspots per management type and Zone produces the fire incidence rate.<sup>7</sup> While not all hotspots represent forest fire per se, in this region, they do indicate vegetation fire, and over much of the Core Zone and Multiple Use Zone would occur in forested areas. Figure 3 shows the percentage of area and of fires for each zone of the MBR.



Community representative performs firebreak maintenance in Uaxactún. Photography: Jaye Renold



**Figure 3.** Percentage of area and of fires (MODIS C6 1 km) in each zone of the MBR. The Multiple Use Zone is sub-divided into different management types. See Table 1 for more detail.

**Table 1.**

The incidence and distribution of fires in different zones and management types of the Maya Biosphere Reserves. Data source: FIRMS MODIS C6.

<b>MBR Zone</b>	<b>Area (thousand ha)</b>	<b>Area (% MBR)</b>	<b>Hotspots (number)</b>	<b>Hotspots (% total)</b>	<b>Fire Incidence Rate*</b>
<i>Multiple Use Zone</i>					
Community Concessions	349.9	16.6	23	1.0	6.6
Inactive Concessions	48.4	2.3	38	1.7	78.5
Industrial Concessions	128.9	6.1	2	0.1	1.6
No Concession	266.7	12.7	300	13.2	112.5
<i>Buffer Zone</i>	463.8	22.1	792	34.9	170.8
<i>Core Zone</i>	844.2	40.2	1114	49.1	132.0
<b>Total</b>	<b>2101.9</b>	<b>100.0</b>	<b>2269</b>	<b>100.0</b>	<b>108.0</b>

\*Fire incidence rate = (number of hotspots/thousand ha per MBR zone type)\*100

Based on the MODIS data (Table 1, Figure 1), the overall fire incidence rate for the MBR was 108.0 for the 2017 fire season. The community concessions, inactive concessions, and industrial concessions were all below this number, suggesting that these management areas did better than would be expected all things being equal. The Buffer Zone did the most poorly by this measure, with a fire incidence of 170.8. Perhaps most unexpected given the theory behind protected areas was that the Core Zone of the MBR had a higher fire incidence rate than the average rate across all zones. The high fire incidence in the Core Zone was not consistent across the area, as 65.8 percent of the fires detected in MODIS occurred in only 39.9 percent of the Core Zone landscape: Laguna del Tigre National Park and Biotope. An additional 28.7 percent of the fires occur in the Sierra del Lacandón National Park, which makes up about 10 percent of the Core Zone. Overall, 32.3 percent of all 2017 fires in the MBR took place in Laguna del Tigre.

**Table 2.**

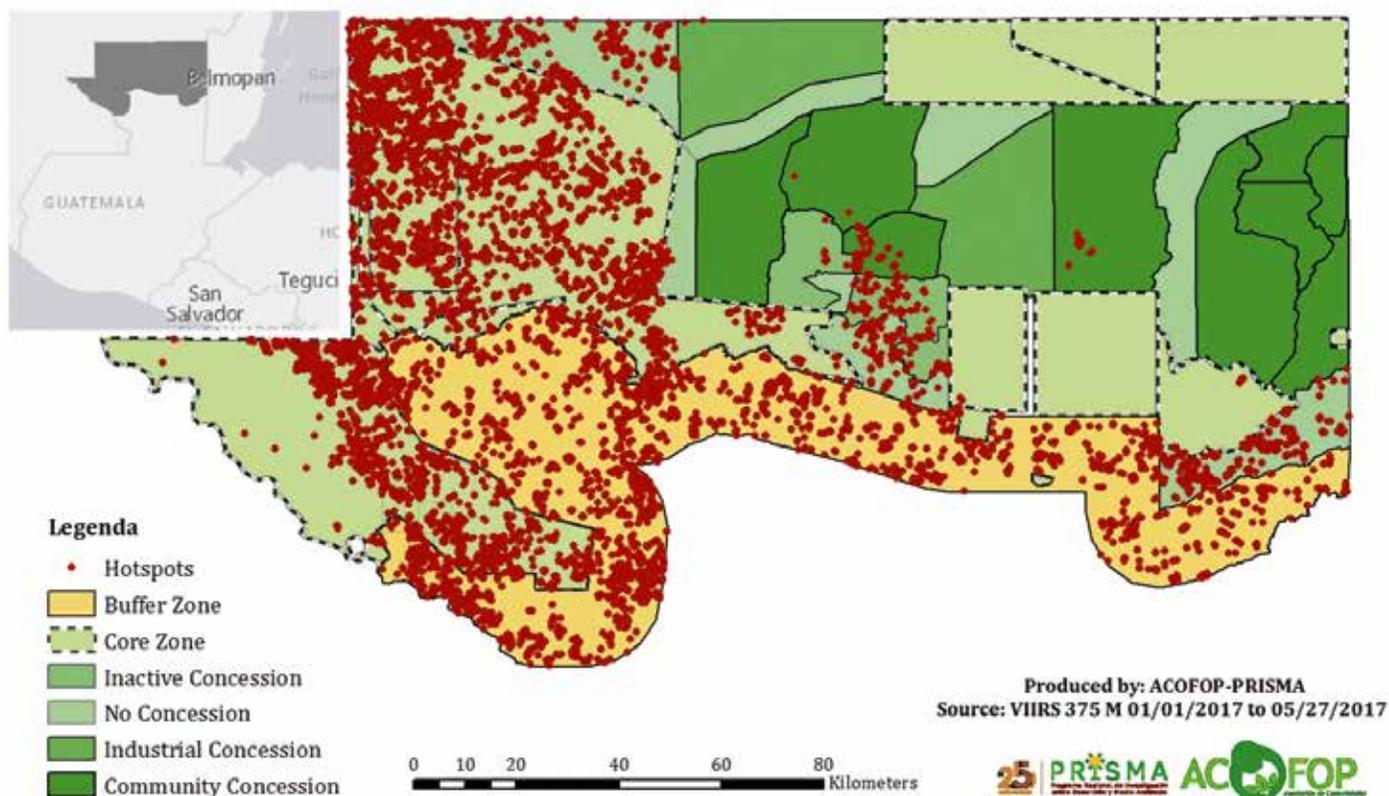
The incidence and distribution of fires in different zones and management types of the Maya Biosphere Reserves. Data source: FIRMS VIIRS 375 M.

<b>MBR Zone</b>	<b>Area (thousand ha)</b>	<b>Area (% MBR)</b>	<b>Hotspots (number)</b>	<b>Hotspots (% total)</b>	<b>Fire Incidence Rate*</b>
<i>Multiple Use Zone</i>					
Community Concessions	349.9	16.6	60	0.8	17.1
Inactive Concessions	48.4	2.3	109	1.4	225.2
Industrial Concessions	128.9	6.1	2	0.0	1.6
No Concession	266.7	12.7	965	12.4	361.8
<i>Buffer Zone</i>	463.8	22.1	2526	32.4	544.6
<i>Core Zone</i>	844.2	40.2	4132	53.0	489.5
<b>Total</b>	<b>2101.9</b>	<b>100.0</b>	<b>7794</b>	<b>100.0</b>	<b>370.8</b>

\*Fire incidence rate = (number of hotspots/thousand ha per MBR zone type)\*100

VIIRS data confirmed these trends (Table 2, Figure 3). At a 375 m resolution, this product detects smaller and less intense fires, thus capturing hotspot activity at a finer scale. This data indicates only 0.8 percent of all fires in the MBR took place in community concessions, even though these groups exert control over 16.6 percent of the MBR. In contrast, and again in keeping with the MODIS data, the incidence of fire in the Core Zone was higher per hectare, with 53.0 percent of the fires despite only containing 40.2 percent of the MBR. The Multiple Use Zone as a whole and each of the management types included within it performed better relative to the expected fire incidence across the entire MBR, with industrial and community concessions the most effective fire management types. Notably, across MODIS and VIIRS, inactive concessions performed better than might be expected relative to the percent of land under this class and to the MBR-wide estimate for fires per thousand hectares.

## Fires Detected in the MBR 2017

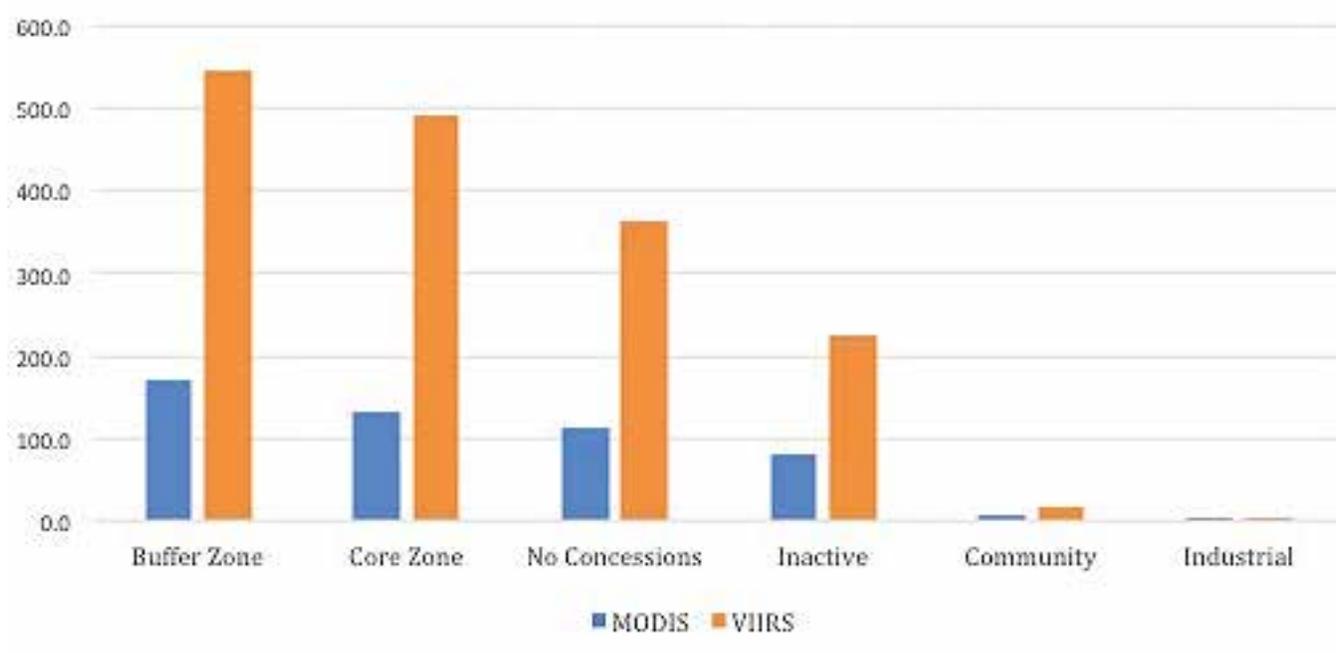


**Figure 4.**

*Forest fires based on the VIIRS 375 M product.* This map shows more fires than the MODIS data, but the distribution of the fires is similar, and concentrated along the western zone of the MBR, in both the Core and Buffer Zones.

Using the MODIS data, a t-test was run to determine the significance of the difference between active community concessions, which found a statistically significant difference between the lower concessions fire incidence rate and the higher Core Zone rate.<sup>8</sup> Including inactive concessions did not affect the significance of the difference between the Core Zone and the Multiple Use Zone concessionated areas, and areas that are or have been under concession perform better in terms of avoiding vegetation fires than protected areas.<sup>9</sup> Because the data on the Buffer Zone is not disaggregated, the significance of the difference of this zone versus the other options could not be determined; however, that its fire incidence rate is higher than that of the Core Zone, it would suggest that the concessions are also significantly more effective at preventing and controlling vegetation fires than in the Buffer Zone. Further, less of the Buffer Zone is forested, so fewer of the fires detected there are likely to affect significant areas of forest directly.

## Fire Incidence Rates by Zone in the MBR 2017



**Figure 5.**

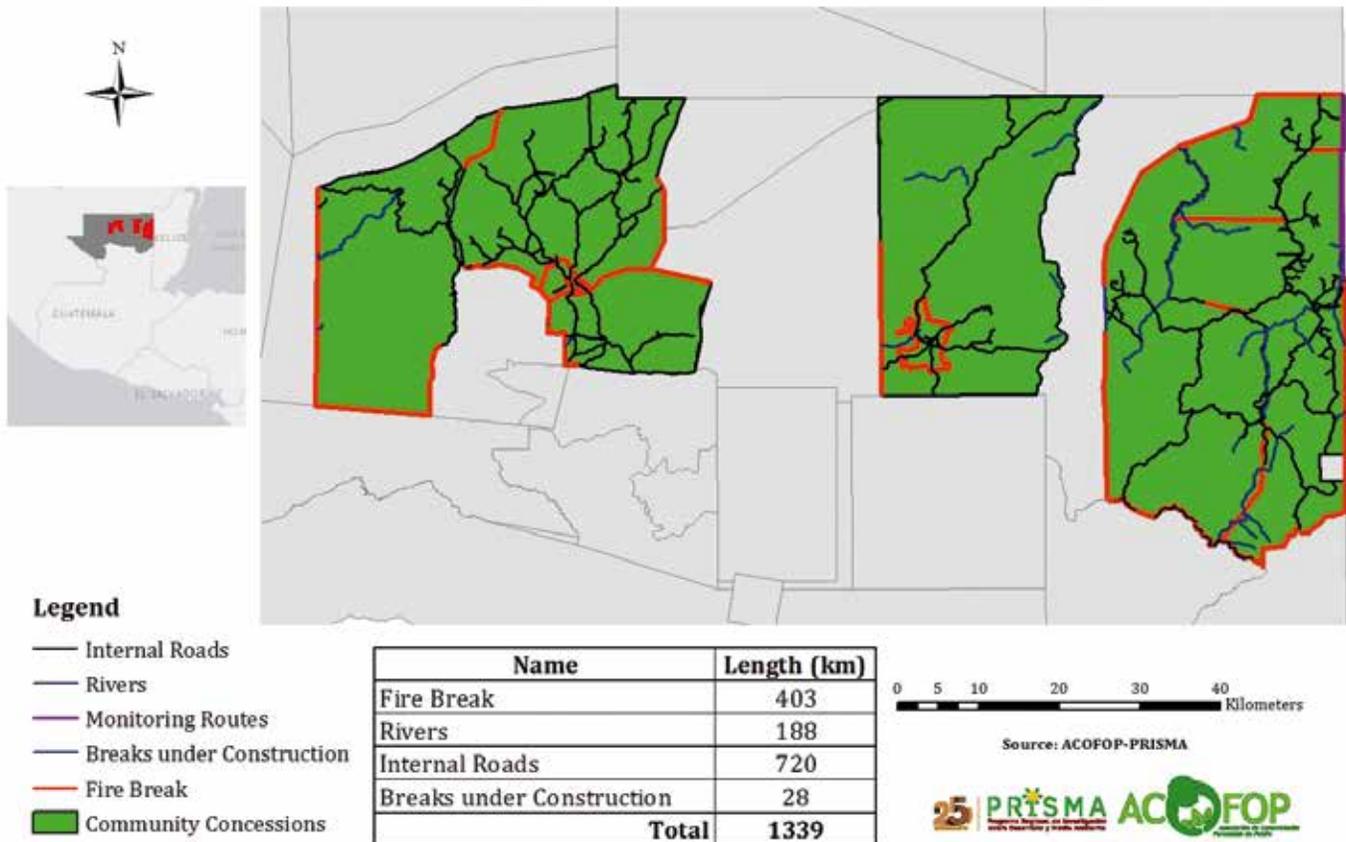
Fire incidence rates by zone and management type. For both MODIS and VIIRS, the Buffer and Core Zones have significantly higher incidence rates than the concession areas of the MBR.

Because this geographic analysis revealed a much lower rate of fire incidence in the concession areas, the researchers reviewed the fire management plans of the community concession organizations to illuminate the range of efforts that they employed regarding fire management. Documents from the nine active community concessions were reviewed (Figure 2) as well as overarching fire plan documents from ACOFOP for the 2017 fire season. Additionally they consulted information from previous fire seasons as provided by ACOFOP as well as CEMEC and CONAP from previous fire seasons. Further, the researchers conducted interviews with forest regents – the technical staff tasked with writing and directing the fires plans in each concession – to better contextualize the documents and the efforts undertaken in the field during the 2017 season.

The outcomes of forest fire prevention and control have been driven by intensive planning and execution of community plans for forest surveillance and monitoring, as well as separate fire prevention and control programs. These plans are developed and financed by each community concession; the development and implementation of these plans are reported to CONAP, charged with the supervision of the community organizations' concessions more broadly.

The effectiveness of fire control and prevention in 2017 was the result of significant cooperation efforts across the nine community concessions operating in the Multiple Use Zone. Community concessions budgeted USD 412,000 to forest fire control and prevention in 2017, allowing for over 1,000 patrol missions. Community concessions organized themselves for over 200 campsites to maintain surveillance and control over community forests, and planned maintenance of 453 kilometers of fire breaks throughout the concession forests (Figure 6).

## Fire Breaks, Rivers and Roads in the MBR Concessions 2017



**Figure 6.**

*Efforts by community concession organizations in the MBR to prevent, manage, and control fires.* Fire commissions and patrols create and maintain fire breaks in concert with existing roads and rivers, to create manmade and natural barriers to the spread of fires. The concessions construct breaks on the edges of their concessions as well as within for those concessions with resident communities that undertake sanctioned subsistence agriculture.

Semi-structured interviews combined with a review of community plans and reports on fire control and prevention reveal a varied set of local strategies to respond to the diversity of threats from fires in the community concessions. Communities facing direct threats from external encroachment allocate more funds per hectare than do communities in the interior of the Reserve. Resident concessions in the interior of the reserve, such as Carmelita and Uaxactún, tend to invest more in internal fire management techniques related to communities' small plots of agriculture, though some exceptions can be found. For example, Árbol Verde has a high expenditure per hectare despite not facing direct threats from the agricultural frontier, which is due to difficult terrain which is costly to monitor. Some funds from Árbol Verde are also allocated to areas outside its own concessions, for example to finance a patrol station (El Tigre) in the Yaxha Najum Naranjo National Park. One other outlier is Cruce a la Colorada, which spends less per hectare on surveillance and control than might be expected (8th of 9), given its location on the front lines of the agricultural frontier; this appears to be related to a lower budgetary capacity, which is in turn linked to violent land-grabs in recent years by illicit actors.<sup>10</sup> Perhaps as a result, this concession had more fires than its neighbors (16 in MODIS); however, it was still more effective than the non-concessioned or national park zone neighbors (a fire incidence rate of 17.4 versus 200.5 for Laguna del Tigre National Park).

Interviews also revealed a costly, yet dynamic and operationally functional, set of organizational arrangements between the concessions that go beyond a mere collection of individual concessions managing their own areas. This study documented a number of examples of inter-community collaboration, such as rotating patrols for shared boundaries between concessions, sharing of resources as well as the coordination of information about threats. ACOFOP often plays a role as a platform facilitating this collaboration, as well as investing additional resources to individual concessions. In addition, in recognition of the low government capacity to stop forest fires in adjacent national parks (and the threat that these fires could pose to community concessions), communities allocate significant resources for community missions to these areas. For example, communities deployed their own resources to the Mirador-Laguna del Tigre Biological Corridor to protect the western forest frontier, while ACOFOP convened governmental and non-governmental actors in Belize to support fire prevention and control efforts in the east. Taken together, all of these actions form a broad geographic “shield” protecting key archeological ruins in the northern MBR, such as the Mirador National Park. The governance contribution of the community concessions is thus not merely the sum of individual organizations: their overall strength is greater due to their interconnection, with an impact that reaches beyond the limits of the concessions themselves.

The relationship between community concessions and governmental authorities, in particular CONAP, is also a critical aspect of the community governance success within the MBR. A number of leaders observed the important role of CONAP as a supervisory authority, citing the process of evaluation as an important step in the process of ensuring that plans are developed and implemented adequately. The communication system to warn communities of hotspots was also consistently cited as an important arrangement helpful to community efforts. Some joint patrols, checkpoints and other collaboration were also cited as important. Nevertheless, several interviewees also expressed discontent with the relationship, related to the high transaction costs of developing plans and reporting to CONAP, especially when this degree of monitoring does not occur in other areas of the MBR. The most common difficulty related to the consistent requests for community resources to support management efforts outside of the community concessions, for which CONAP did not have sufficient resources.

Community concession organizations, in collaboration through ACOFOP and with CONAP, have effectively conserved forest in the MBR during the 2017 fire season, and have been significantly more effective than other management approaches. Over their histories, the concessions have also been successful in avoiding deforestation and conserving important resources.<sup>11</sup> Despite resource challenges, the concession organizations have developed the capacity to plan for emergencies and still retain the flexibility to respond to threats. Cooperation between concessions, such as to maintain fire breaks on the borders between concessions, speak to an innovative yet grounded approach to addressing forest fires and broader forest threats across concessioned areas of the MBR. Overall, the organizations that make up ACOFOP have demonstrated a high capacity and effectiveness in addressing threats like forest fires, reflecting a robust organizational structure and strong commitment to the long-term maintenance of Peten’s forests.



Constant maintenance of fire breaks is one of the keys in the success achieved in preventing and controlling forest fires. Photography: Jaye Renold

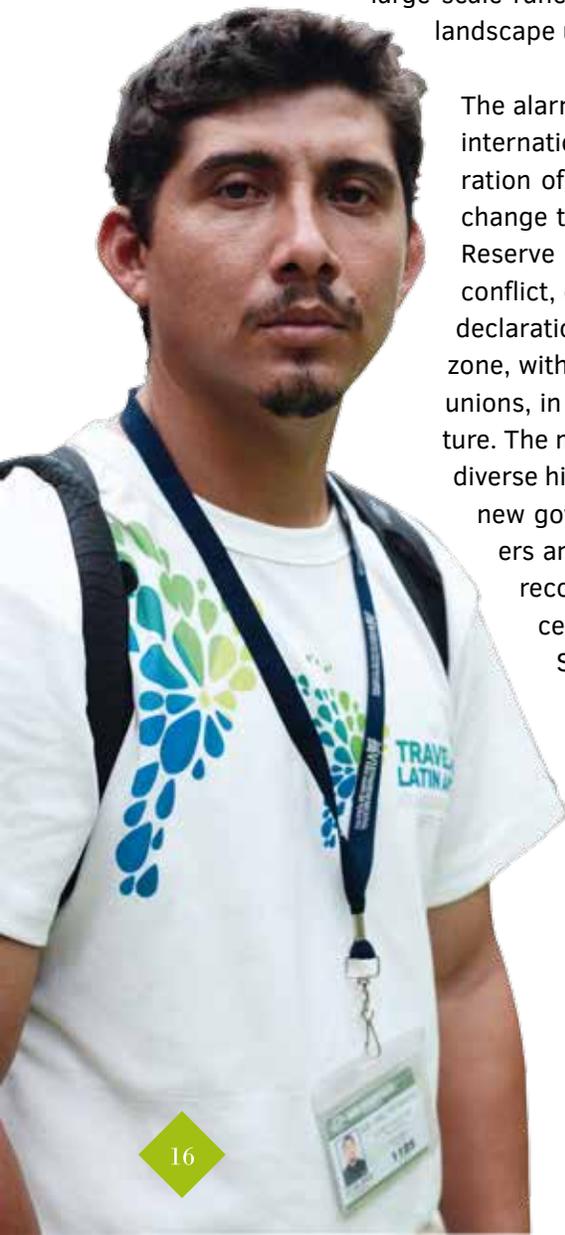
# III

## Historical context for understanding firefighting and fire prevention in Petén

The capacity of community forest concession organizations to effectively address the seasonal threat of forest fires is a result of a dynamic community process born out of struggle, innovation and negotiation, rooted in the particular history of the Petén. For more than half of the 20th century, the Petén was a vast and sparsely populated forest frontier, largely beyond the reach of the national government. Yet the growing demand for land, as well as a renewed focus on securing national borders led the Guatemalan government to use Petén, beginning in the 1960s, as a “safety valve” for land demands in the South.<sup>12</sup> A semi-autonomous government agency aggressively promoted the migration of small farmers and large-scale economic interests alike, including large-scale ranching, farming, and timber extraction – activities that dominated the Petén landscape until the late 1980s.

The alarming levels of deforestation caused by these policies drew both national and international attention to the Petén, and ultimately culminated in 1990 in the declaration of the Maya Biosphere Reserve, covering over half of the Department.<sup>13</sup> This change took place without consultation with the people living within the designated Reserve and outlawed basic livelihood activities, touching off an intense period of conflict, chaos, and deforestation within the area.<sup>14</sup> The communities affected by the declaration of the MBR were diverse in their historic relation to the highly forested zone, with some still rooted in traditional chicle extraction, others organized in timber unions, in addition to other recent migrant communities primarily engaged in agriculture. The movement in support of these communities’ rights ultimately overcame these diverse histories and the groups organized themselves into a unified front vis-a-vis the new government restrictions.<sup>15</sup> By actively lobbying the government and its backers and proposing an alternative to strict protection, these communities achieved recognition of their rights through a new legal form of renewable 25-year concessions granted to organized communities, conditional upon obtaining Forest Stewardship Council (FSC) certification. Within a few years, these community organizations represented in ACOFOP generated benefits for over 30,000 people and managed over 400,000 ha, cited as “the largest extent under community concession in the world.”<sup>16</sup>

Official community tour guide, Uaxactun.  
Photography: Jaye Renold



Harvesting of xate (a decorative palm) in the Carmelita community concession. Photography: Jaye Renold



The community concession model laid the foundation for the emergence of new and dynamic forms of organization with far-reaching social and economic implications. FSC certification requirements meant that during their early years, the concessions focused heavily on building the technical knowledge necessary for compliant timber management. Initial efforts also focused on developing new enterprise capacities, involving the complex administrative tasks of managing forest harvesting, transportation, and market linkages for forest products. NGOs played a significant role in supporting these capacities in early stages, but were soon phased out as communities gained capacity to manage these aspects autonomously. Community social arrangements around the concessions also evolved, as supporting community-level health and education became important areas for investing forest product income.

Early community management focused heavily on high-value mahogany, but the concessions recognized early on that dependence on a single species was a vulnerability of the management model. Communities responded to this challenge by diversifying into other types of timber species. Perhaps most importantly, the concessions pushed the government to understand the importance of broad-based forest livelihoods, beyond timber production. They negotiated for the recognition of non-timber forest activities as part of the concession model, allowing the formal incorporation and expansion of economic activities such as *xate* (a decorative palm), as well as developing new income from community tourism. Communities also developed an umbrella organization called FORESCOM to access new markets, and developed new productive chains, progressing significantly in advanced



The gathering of seeds and the elaboration of crafts are part of livelihood activities based on non-timber forest products carried out by communities, especially by women. Photography: Jaye Renold

timber product activities. In 2014, ACOFOP became one of the few community organizations in the world that has managed to achieve certified Verified Emissions Reductions - a certification demonstrating the contribution of the community concessions towards combatting climate change.

The communities have thus driven a notable process of increasing sophistication in community forest enterprises. Communities have come to see that their economic and social well-being is aligned with that of the forests that they manage, producing a “culture of conservation” that produces concrete and broad based economic and social results<sup>17</sup> that underpin the sustainability of the concessions.<sup>18</sup>

The ecological outcomes of this model have been the subject of intense scrutiny by the national government, research institutes and universities around the world. Congruent with the findings of this study related to fires, this broad body of research has consistently demonstrated the effectiveness of the community concessions, contrasting sharply with the Core Zone, especially the largest national parks in the MBR, Laguna del Tigre y Sierra del Lacandon. A 2012 study, for example, found that FSC certified concessions have seen deforestation rates of 0.008 percent between 2001 and 2009, in comparison to the national park average of 1.18 percent during the same period. Even including the inactive concessions, the average deforestation rate of concessions in the MBR between 2001 and 2009 stood at 0.45 percent, over two and a half times lower than the average rate in the MBR.<sup>19</sup> A 2016 study showed deforestation in the community concessions between 1994 and 2015 to be 2.97 percent, compared with 21.87 percent in the Core Zone, and 40.73 percent in the Buffer Zone.<sup>20</sup> While some debate continues on the relative weight of land use category in relation to other variables (topography, distance to roads, population density) in explaining deforestation, there is broad scientific consensus that the community concessions have been at least as effective as the Core Zone sections of the MBR.<sup>21</sup>

Despite these successes, the community concessions continue to face active threats both on the ground and from policy initiatives that threaten to undermine the rights of the concession model. Highly coveted oil reserves lie beneath the entire MBR, and a major oil concession was granted inside the Laguna del Tigre National Park, facilitating active migration within the area; the community concessions have actively fought similar proposals

inside the concessions. Other infrastructure and land policy programs have driven a dramatic expansion of oil palm production, resulting in the displacement of both small scale Q'ueqchi' farmers and large-scale cattle ranching from Alta Verapaz, Izabal and Southern Petén towards the MBR.<sup>22</sup> Drug-trafficking and other illicit activity have exacerbated these dynamics, as much of the Southern Petén and Laguna del Tigre have been appropriated for illicit trafficking corridors and money laundering operations. Perhaps the most pressing threat, however, can be found in current proposals for terminating community rights in favor of a large-scale tourism model around the Mirador National Park. Taken together, these interests represent a formidable and imminent threat to the renewal of the community concessions.



Coordination of patrols for surveillance and control within the community concessions. Photography: Paul Redman



# IV

## Conclusion: models for forest governance in the Petén

The Petén offers a natural experiment through which to analyze the divergent outcomes from the implementation of different forest governance models, specifically the government-managed protected area versus the community forest managed concession. The former adopts a traditional approach, in which rules for biodiversity and forest management are designed and implemented by the government. Environmental authorities, along with police and military forces, are entrusted with implementation of these rules. This approach categorizes local human populations largely as threats to be controlled or regulated by government authorities. Significant restrictions are placed over land use; special permission for fires, tree felling, and land use change are required of remote communities with low levels of education and poor access to government services. The organizational requirements for such an approach call for significant permanent funding, exceptional government effectiveness and efficiency, and low levels of corruption.

Our results suggest that the Guatemalan government has not demonstrated the capacity to effectively implement the traditional protected area model, especially under active pressure from small-scale farmers, industrial agriculture, cattle ranching, fossil fuel extraction, and illicit activity. While the results of this study suggest that the national park approach may be viable in small-scale areas linked to high levels of tourism revenue and inter-institutional support, such as Tikal National Park, it is clear that the organizational requirements for national parks have far exceeded government capacity across significant portions of the MBR and left government agencies without local counterparts able to sufficiently fill this vacuum.

The co-management approach taken with the community concessions clearly contrasts with the traditional approach, and the results of this analysis suggest that this model is much more appropriate for the particular conditions and capacities of both the Guatemalan government and local communities. The communities' fire management plans are the result of years of experience in large-scale community collaboration based on the rights granted in the 25-year community concession contracts. Community rights have been the foundation for a governance system that promotes cooperation and the long-term valuation of resources. Such an approach has cultivated local capacities and interests by aligning the fate of the communities with the well-being of the forest and its resources.

According to Decree 5-90, Guatemala established the Maya Biosphere Reserve for the conservation of biodiversity, the protection of forests, the preservation of cultural patrimony, and the sustainable development of the region. Given the negative impact of forest fire on all of these key elements, the evidence presented here demonstrates that the community concessions have played a significant role in meeting the stated goals of the MBR. These results are congruent with the broader historical effectiveness of community concessions in maintaining the forest cover and biodiversity that are central to concession livelihoods. They also conform with the findings of other researchers regarding the efficacy of community-managed forests and protected areas in Latin America.<sup>23</sup> Policymakers should therefore act quickly to respond to the growing threats over the area by renewing the community concessions of the MBR.



# Endnotes

- 1 The researchers acknowledge the use of data and imagery from LANCE FIRMS operated by the NASA/GSFC/Earth Science Data and Information System (ESDIS) with funding provided by NASA/HQ.
- 2 Davis, A. and S. Kandel (2016). Conservation and Community Rights. San Salvador: Fundacion PRISMA, Clark University & The Rainforest Foundation United States; Radachowsky, J., V.H. Ramos, R. McNab, E. H. Baur, and N. Kazakov (2012). Forest concessions in the Mayan Biosphere Reserve: A decade later. *Forestry Ecology and Management* 268: 18-28.
- 3 A small group of three concessions, covering 2.3% of the RBM, are not currently certified. This includes San Miguel, a pilot model for the community concessions, which provided valuable lessons but was discontinued due to a low initial resource endowment stemming from prior illegal logging. La Colorada and La Pasadita lost their certification due to violent external land grabs. Currently, communities in La Colorada y San Miguel are working to recover these areas and achieve certification.
- 4 MODIS Collection 6 NRT Hotspot / Active Fire Detections MCD14DL. Available on-line [<https://earthdata.nasa.gov/firms>].DOI: 10.5067/FIRMS/MODIS/MCD14DL.NRT.006. (accessed 27 May 2017)  
NRT VIIRS 375 m Active Fire product VNP14IMG. Available on-line [<https://earthdata.nasa.gov/firms>]. DOI:10.5067/FIRMS/VIIRS/VNP14IMG. NRT.001. (accessed 27 May 2017).
- 5 MODIS C6 hotspots indicate 1 km pixels in which at least one active fire is detected during a pass by the satellite. VIIRS 375 m detects hotspots at a higher resolution, thus picking up more and smaller fires. The other phenomena that these satellites may detect include gas flaring and active volcanoes, which are not of significant concern in the MBR; thus, the fires detected in the MBR represent vegetation fires. With both of these products, weather factors (such as cloud cover) are more likely to obscure a fire, especially if small, than to over-report. Given consistency in climate across this zone, weather-dependent caveats for the FIRMS data products likely do not influence the findings presented herein.
- 6 Polygons of the MBR courtesy of CEMEC/CONAP. The new dataset was produced in ArcGIS 10.1 by clipping the MODIS and VIIRS data with the MBR polygons and then doing a spatial join. Data was then extracted to Excel for further analysis.
- 7 The fire incidence rate was calculated by dividing the number of fires in a zone by the area (thousands of ha) and multiplying by 100. This rate captures the relative differences in occurrence of fire between zone/management type as standardized for the size of that land use class, while allowing for greater ease of comparison.
- 8 *t-value*: 2.51179, *p-value*: 0.018295, significant at  $p < .05$ .
- 9 *t-value*: 2.52139, *p-value*: 0.017044, significant at  $p < .05$ .
- 10 Radachowsky et al. (2012)
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