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Title of the Presentation: " Community and Industrial Forest Concessions: are they effective at reducing forest loss and does FSC certification play a role?"

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Selected Paper prepared for presentation at the 2023 Agricultural & Applied Economics Association Annual Meeting, Washington DC; July 23-25, 2023

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Introduction

Recognizing the important roles tropical forests play in biodiversity conservation, carbon sequestration, and local economic development, significant efforts have been made to reduce deforestation while still providing a livelihood for local communities that are often dependent on forest resources (Bowler et al. 2010). In an effort to achieve these goals, two approaches have grown in popularity the past few decades, forest certification schemes such as Forest Stewardship Council (FSC) certification, and an increased focus on community forest management (CFM) coming out of the trend toward devolution and decentralization of forest management (Rametsteiner and Simula 2003; Bowler et al. 2008; Somanathan et al. 2009; Hyde 2016). The literature on these two forest management strategies has grown as a result of their increasing prevalence in forests across the tropics, where 16 percent of all forestland worldwide is designated for community management (Rights and Responsibilities Initiative, 2018). However, Burivalova et al. (2017) identify a gap in the literature that arises when it comes to rigorous studies examining the impacts of these two approaches combined. Furthermore, understanding how community forest management and certification perform across different types of forest tenure regimes and community groups is important to determine the most appropriate policies for reducing deforestation, particularly given the increasing threat of climate change. To that end, this paper conducts a robust analysis of the impact of mandatory forest certification in Guatemala's Maya Biosphere Reserve (MBR) across a heterogeneous mix of community managed and private industrial forest concessions.

Forest certification is a market-based mechanism that aims to preserve forests and decrease deforestation through sustainable harvesting and logging practices (Auld et al. 2008). The first certification scheme was created in 1993 by the Forest Stewardship Council (FSC) with the mission of promoting "environmentally appropriate, socially beneficial, and economically viable management of the world's forests" (FSC 2015). Today, the FSC has more than 200 million hectares of certified forests worldwide. To become certified, logging concessions have to abide by a set of sustainable forest management practices, such as reduced impact logging, and undergo independent third-party verification. In return, concessions gain access to specialized markets for certified wood that sells at a price premium (Aguilar and Vlosky, 2007). In most cases, logging concessions voluntarily choose to become certified. The MBR in Guatemala is a unique case study where FSC certification is a mandatory requirement that local forest managers must obtain in order to access forest resources (Carrera et al. 2006). Additionally, the MBR is one of the few places where communities are managing certified forest concessions. The vast majority of FSC certificates are for privately managed forests (64 percent), and community managed forests make up just over 2 percent of certified land worldwide (FSC 2016).

The concessions in the MBR provide the opportunity to compare certified industrial and community-managed forest concessions in close proximity to each other within the same reserve, which allows for a more direct comparison of the two management approaches and reduces the likelihood of unobserved confounding factors that are likely to be present in more common studies that compare forest management strategies across multiple locations (Blackman 2015). Previous studies comparing industrial management with a more community-focused approach to sustainable forestry claim that industrial concessions are more efficient[1] (Karsenty et al. 2008). However, this assertion is often based on the assumption that the alternative to an industrial concession area is open access land-use, which is more likely to result in forest loss if local communities live in close proximity to the area with unrestrained access. On the other hand, Mendes and Macqueen (2006) advocate for a more small-scale approach to forest management as a pro-poor policy that gives local communities access to forest resources and provides potential for economic development. Radachowsky et al. (2012) provide insight on the question of industrial verses community management in their review of forest concessions in the MBR, finding that in some cases, community concessions may perform as well as or even better than industrial concessions. However, the authors do not control for external factors in a robust empirical analysis. Blackman (2015) finds that the community concessions in the MBR that allow for sustainable timber extraction perform as well as or better than the strictly protected areas also in the reserve, but excludes the industrial concessions from the analysis due to insufficient observations of deforestation in the land cover data from the years 2001 to 2006. To our knowledge, there has not been an empirically robust analysis comparing industrial and community forest management practices that also requires both groups to be certified.

This study uses forest loss data from 2000 to 2017 (Hansen et al. 2013) to examine whether the FSC certified concessions reduce deforestation in the MBR. Within the MBR, there are twelve community concessions and two industrial concessions. The community groups vary across a number of cultural and socio-demographic characteristics, such as income, educational attainment, and previous forest experience (Radachowsky et al. 2012; Fortmann et al. 2017; Bocci et al. 2018; Butler 2022). The differences among the community groups in comparison with the industrial concessions provide an opportunity to examine the impact of forest certification across different institutional approaches to forest management. We employ a random effects model to examine the effectiveness of the community and industrial concessions in reducing deforestation compared to a matched control group of forest pixels within the MBR, not under a formal management scheme. Our findings suggest that sustainable forest practices tied to concession management have continued to reduce deforestation in the MBR, but the impacts vary across the different community and industrial concessions types. A secondary part of our analysis examines the different mechanisms by which FSC certification reduces deforestation, which are based on the requirements of sustainable forest management practices and increased market access that often comes with a price premium for certified wood. Our results suggest that the implementation of sustainable logging based on approved management plans is the main mechanism by which certification reduces deforestation, and the added benefit of specialized market access yields a small additional reduction in some cases, but the results are generally inconclusive.

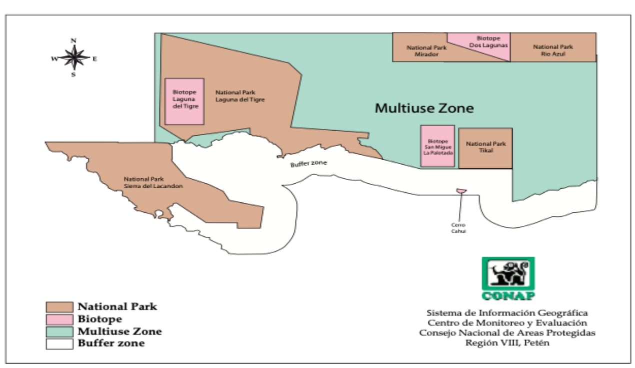
Our paper broadly contributes to the current literature by providing a robust analysis of certified community forest management (see Burivalova et al. 2017) and extending this analysis to examine how different types of tenure schemes (community vs. industrial) perform under certification. Additionally, this paper provides insight into the longevity of certified CFM as a viable long-term management strategy.

The remainder of this paper is organized as follows: the next section provides background on the creation of the forest concessions in Guatemala's MBR, followed by a theory of change section. Then, we describe data and methods used in the analysis and the final sections present the results with a discussion of the implications of our findings.

Background

The Maya Biosphere Reserve (MBR), in the northernmost part of Guatemala, comprises 2.1 million hectares of land. It is divided into three zones: a core zone (national parks and biotopes), a buffer zone, and a multiple-use zone (MUZ) (see Figure 1), which includes close to half a million hectares of broadleaf forest and is home to the community and industrial forest concessions (Carrera et al. 2006; Radachowsky et al. 2012). Prior to the formation of the reserve, the forests of the Petén were being destroyed at an alarming rate with the main drivers being illegal logging, looting of archeological sites, forest fires, and the continued encroachment of the agricultural frontier. Much of this was due to an influx of people pouring into the region in search of refuge from the civil war or wanting to claim land under the rural colonization policy promoted by the *Fomento y Desarrollo de Petén* (FYDEP) which was a state-run military enterprise (Nittler and Tschinkel 2005; Carrera et al. 2006; Gomez and Mendez 2008; Radachowsky et al. 2012). The area was also home to 13 industrial logging companies that primarily extracted mahogany under renewable logging contracts not tied to any management plan. The rampant deforestation garnered international attention by a number of conservation organizations and ultimately led to the establishment of the area as a biosphere reserve in 1990 and included the international designation of Tikal National Park as a UNESCO World Heritage site. With the creation of the reserve, the *Consejo Nacional de Areas Progidas* (CONAP) took over management of the region and revoked all logging contracts. In their place, CONAP agreed to allow for the creation of sustainably managed forest concessions under the condition that they must become FSC certified within three years of establishment (Carrera et al. 2006).

[Figure 1. Maya BiosphereReserve zones]



Source: CEMEC-CONAP

The decision to allow sustainable timber extraction within the reserve, as opposed to strict protection, was a controversial one but was ultimately approved based on the belief that providing property rights to the forest through forest concessions combined with FSC certification would promote sustainable, long-term management of the forest (Hughell and Butterfield 2008). The fact that forest certification was mandatory in order to obtain concession rights is somewhat unique, whereas in most other parts of the world, FSC certification has remained a voluntary enterprise (Carrera et al. 2006). The concession granting process was driven by a joint partnership between CONAP and the Tropical Agricultural Research & Higher Education Center (CATIE) as part of the Maya Biosphere Reserve project funded by USAID (Carrera et al. 2006). Each concession worked with an NGO partner throughout the concession granting and certification process that provided technical expertise and financial assistance.

Twelve community concessions and two industrial concessions were established in the MBR between 1994 and 2001 (Monterroso and Barry 2007).[2] The designation of the concession boundaries was based on forest management units that came from a forest inventory that was conducted as part of the development plan for the Petén (Nittler and Tschinkel 2005). Initially, concessions were slated for six communities located inside the reserve, but recognition of the need for additional groups to manage the large forest area of the MUZ resulted in an additional six concessions allocated to community groups living outside of the reserve (Nittler and Tschinkel 2005; Radachowsky et al. 2012). The decision to allocate concessions to industrial corporations was heavily debated due to conservation organizations wanting to keep the forest resources in the hands of the local communities, but in the end, two corporations that had been

[2] Four additional forest management units were awarded forest concessions, but these areas were outside of the reserve, given to cooperatives or municipal Ejidos

previously established in the Petén, *Paxban* and *La Gloria*, were also granted forest concessions (Nittler and Tschinkel 2005).

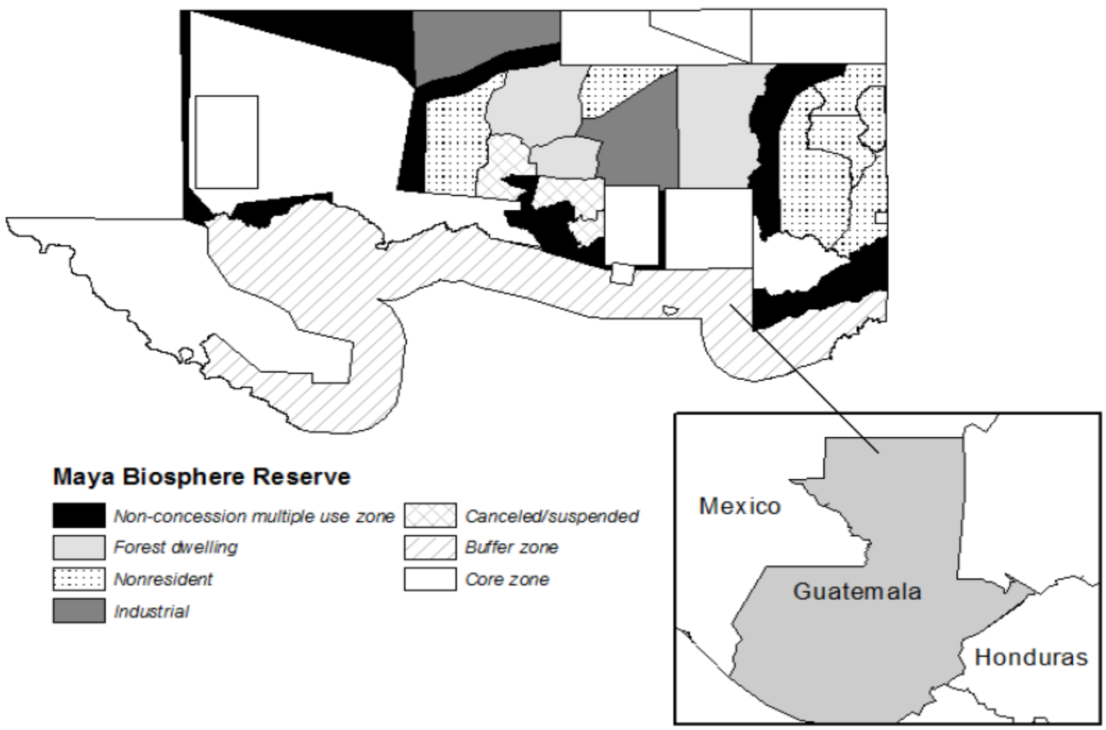
Forest Concessions Types

Among the twelve community concessions, there are three sub-groups based on the location of the concessions and community characteristics which have been well documented in the literature: nonresident, long-inhabited, and recently-inhabited concessions (Nittler and Tschinkel 2005; Gómez and Méndez 2007; Radachowsky et al. Fortmann et al. 2017; Bocci et al. 2018; Butler 2022). Six of the concessions are categorized as nonresident where the members live outside the concession boundaries, typically in larger towns and more urban centers in the buffer zone. The majority of these concessions are in the eastern half of the reserve, with the exception of *San Andres*. Many of the members of these communities already had logging experience prior to the establishment of the MBR and the creation of the community forest concessions granted them legal access to the forest to continue their operations (Gómez and Méndez 2007). Additionally, nonresident concession members typically have higher levels of education and greater average income than the other two types of community groups (Fortmann et al. 2017; Bocci et al. 2018). The remoteness of the nonresident concessions further distinguishes them from the resident concessions which face more external land use pressures since the community members live inside the concession boundaries (see Figure 2).

The long-inhabited concessions include two communities, *Carmelita* and *Uaxactún*, where the members have resided in the Petén since the mid-1920s. These communities have a long history of forest extraction and have traditionally relied on forest products, such as *chicle* and *xate*, for their livelihoods (Gómez and Méndez 2007). Relative to the other two groups, members in the long-inhabited concessions are more educated and have higher average income than the recently-inhabited members, but are less educated with lower average income than the nonresident members (Fortmann et al. 2017; Bocci et al. 2018). Finally, there are four recently-inhabited concessions located in the central region of the reserve. These communities are comprised of a heterogenous mix of members from different ethnic groups that moved to the region in search of land during the period of rural colonization prior to the formation for the reserve, or were displaced from the land during the civil war and returned during the mid-1990s (Gómez and Méndez 2007). These communities had no prior experience with forestry and primarily came from agricultural backgrounds. They have the lowest levels of education and income on average among the three types of concessions (Fortmann et al. 2017; Bocci et al. 2018). The recently-inhabited concessions are also the most exposed in terms of proximity to roads and population centers, relative to the other two types of community concessions.

In addition to the cultural and socio-economics differences among the community concession members, the forest areas awarded to the communities are also heterogenous with regards to size, forest characteristics, and stock of trees, with some having larger quantities of the more valuable species such as mahogany and cedar (Gómez and Méndez 2007). Despite the differences among the three types of community concessions, the general approach for working with these groups and guiding them through the process of gaining access to a forest concession and becoming certified was the same. Not surprisingly, the concession groups have had varying degrees of success when it comes to maintaining their forest concession and certification status. Since their establishment, all four of the recently-inhabited concessions have been cancelled and/or suspended at some point for not complying with their management plan (Radachowsky et al. 2012). Currently, only one of these concessions is still active, *Cruce a la Colorada*. The differences among these concessions with regards to their forest experience, background, and demographics have likely contributed to this outcome along with the characteristics of the forest concessions themselves regarding size, proximity to roads, and external pressures on the land, including the presence of narco-drug trafficking and illegal cattle ranching in the region (Radachowsky et al. 2012; Hodgdon et al. 2015; Devine et al. 2020).

[Figure 2: Map of Community and Industrial Concessions in the MBR]



The two industrial concessions, *Gibor* and *La Gloria*, are located within the central region of the reserve also in the MUZ (see Figure 2). These concessions are only allowed to managed and extract timber, unlike the community concessions which are allowed to harvest non-timber forest products (e.g. *chicle* or *xate)* within the concession boundaries (Radachowsky et al. 2012). Like the community-managed concessions, the industrial concessions had to work with an NGO to develop a sustainable forest management plan approved by CONAP. Once approved, they were granted exclusive land use rights to a forest management unit and had to obtain FSC certification within three years of establishment (Radachowsky et al., 2012). Unlike the community-managed concessions, industrial concessions are managed more like a private corporation. Rather than concession member households being directly responsible for implementing the sustainable forest management plan, the responsibility lies with the concession managers. Also, instead of collectively sharing in concession profits through dividends, industrial concession workers only earn a wage, which is about 10 to 12 U.S. dollars per day. Although some industrial concession workers receive limited in-kind benefits such as a death benefit or scholarships, many only receive a seasonal wage for harvesting timber and selling more refined forest products such as furniture, floor boards, and musical instruments (Diaz, 2018; Gibor, 2019). The two industrial concessions are located in more remote regions of the reserve with limited access by road and no local inhabitants.

Table 1. Concession Type, Size, and Certification Status

Concession Type	Concession Name	Area (ha)	Year formed	Year Certified	Certification Status
Industrial	Gibor (Paxban)	66,458	1999	2001	Active
	La Gloria	64,869	1999	2003	Active
Nonresident	Suchitecos	12,117	1998	1998	Active
	Laborantes	19,390	2000	2003	Active
	AFISAP	51,940	2000	2001	Active
	Arbol Verde	64,973	2001	2002	Active
	CUSTOSEL	21,176	2002	2004	Active
	El Esfuerzo	25,328	2002	2004	Active
Long-inhabited	Carmelita	53,797	1997	1999	Active
	Uaxactun	83,558	2000	2000	Active
Recently-inhabited	Cruce a la Colorada	20,469	2001	2005	Active
	La Pasadita	18,217	1997	1999	Cancelled
	San Miguel	7,039	1994	1999	Cancelled
	La Colorada	22,067	2001	2005	Cancelled

Notes: Information from this table comes from Carrera et al. 2004 and Rosales et al. 2010. Certification status is current as of the year 2022 from the FSC website.

Theory of Change

This section provides an overview of the theory and mechanisms by which community forest management and certification reduce forest cover loss, a discussion of the primary drivers of deforestation in the multiple-use zone (MUZ) of the reserve, and how they are controlled for based on our selection of covariates in the analysis.

The MBR was established in an effort to stop rampant deforestation that was taking place in the region driven by logging, forest fires, and land use change from an influx of migrants, many of whom were fleeing from conflict from the Guatemalan Civil War (Bocci, 2021), and primarily had backgrounds in agriculture and ranching (Nittler and Tschinkel 2005). Prior to the creation of the MBR, the Petén's forests were subject to indiscriminate logging with no provisions for management plans or acknowledgment of sustainability and conservation goals (Carrera et al. 2006). Under this new management regime for the reserve, two mechanisms were jointly implemented to reduce forest loss in the MUZ, community forest management (CFM) combined with mandatory forest certification through the FSC.

Worldwide, CFM gained popularity in the 1970s with the understanding that governments often lack the appropriate resources and infrastructure to manage and protect local forests, and that beneficial outcomes could be attained by devolving the management rights to local communities that often have ties to the forest and depend on its resources for their livelihood (Curran et al. 2004; Charnley and Poe 2007; Bowler et al. 2008; Burivalova et al. 2017). By allocating property rights to local communities, a tragedy of the commons outcome can be avoided, (Gordon, 1954; Scott, 1955; Bowler et al., 2008) but even more so, additional benefits may occur such as more ecologically sustainable forest management and greater local control which has been associated with economic and social benefits for local communities engaged in CFM (Colfer 2005 a,b) For a more thorough discussion on the theory and practice of CFM see Charnley and Poe (2007) and Pagdee, Kim, and Daugherty (2006).

In the MBR, CFM is implemented by allocating forest concessions to local community groups that work together with an NGO to develop a sustainable forest management plan. The concessions allow member households to have exclusive access to sustainably harvest and sell forest resources in exchange for monitoring and protecting the land. The ability to exclusively profit from harvesting forest resources provides households with the incentive to protect and maintain the health of the forest in the long-term or risk losing their access rights. Bocci et al. (2018) found that concession members have profited from participating in concession management, which suggests that devolving management rights has likely provided members with an incentive to reduce deforestation in the reserve.

Forest certification through the FSC was a further requirement of concession management in the MBR for both the community and industrial concessions. The certification model is based on the premise that consumers are willing to pay more for sustainably produced wood products, which is validated by third party auditors that ensure sustainable management and reduced impact logging (RIL) practices are being followed (Auld et al. 2008). Certification provides added incentives for communities to reduce deforestation and degradation through two main mechanisms, sustainable forest management practices and price premiums for certified timber in specialized markets. In theory, the forest certification scheme is incentive compatible if the benefits of selling certified timber outweigh the increased costs of the RIL practices and audit fees that come with maintaining certification (Auld et al. 2008).

To become certified, the community concession members first had to register as an official association. Each concession also partnered with an NGO to create an environmental management plan that was approved for a 40-year cycle, as well as an annual operating plan that is reviewed and authorized every year (Centralized National Risk Assessment for Guatemala, 2018). The concessions have the ability to renew their status after a period of 25 years which provides added incentives for long-term, sustainable management. National certification standards for Guatemala were not established at the time most of the concessions were becoming certified, so they followed the generic FSC standards (Carrera et al. 2006). This includes reduced impact logging practices (e.g. directional felling, planning of roads and skid trails, and using lightweight machinery), regular monitoring of the forest, and annual audits conducted by a third-party evaluator (Putz et al. 2008; Radachowsky et al. 2012). Additional benefits of concession membership include legal access to the forest resources within the forest management unit, jobs, and in some cases, members receive annual dividend payments depending on whether or not the concession association is registered as a for-profit organization. The community concessions are also responsible for providing in-kind benefits, such as life insurance or loans, to the members as well as local community benefits such as scholarships or medical supplies which help to garner broader community support for the concessions (Radachowsky et al. 2012; Bocci et al. 2018).

If a concession is unable to obtain certification, or has it revoked due to lack of compliance, the concession is suspended or canceled This has happened in three of the four recently-inhabited concessions, which all had their certification status terminated or suspended by 2004 (Radachowsky et al. 2012). In some cases, households in cancelled concessions lost their rights over any land use in the reserve and were evacuated from the region, as was the case with *La Colorada*. In other cases, residents were allowed to remain within the reserve even after it was cancelled. The rights to harvest certain timber or non-timber forest products within the reserve also varied among the concessions (Radachowsky et al. 2012). Since the majority of the recently-inhabited concessions struggled with their management plans from the outset and never successfully functioned as a certified concession, we have excluded three of them from the analysis since our forest cover data started in 2001 shortly before they were terminated. While *Cruce a la Colorada* also struggled as a concession, it has been able to overcome the challenges other recently-inhabited concessions were unable to (Devine et al. 2020) and thus is the focus of the recently-inhabited concession results.

The second mechanism by which certification incentivizes reduced forest cover loss is based on access to specialized markets for certified wood. If members can obtain higher prices for certified timber and expand their market base, they have greater incentive to protect and sustainably manage the forest. Initially, gaining access to international markets for certified wood proved to be a challenge for the concessions for a number of reasons. There was nonexistent demand for certified wood domestically and the concessions lacked the business and marketing expertise needed to gain entrance to international markets. Additionally, harvest volumes for the highest value wood species, principally mahogany and Spanish Cedar, were low and concessions struggled with providing high quality sawn wood (Carrera et al. 2006; Radachowsky et al. 2012). In order to support the long-term sustainability of the concessions, FORESCOM was established in 2003 as the technical and business arm of the *Asociación de Comunidades Forestales de Petén* (ACOFOP) which is a not-for profit community organization that aims to promote the socioeconomic development of local forest communities (Gómez and Méndez 2007). With the assistance of Rainforest Alliance, FORESCOM has been able to successfully promote lesser known species of wood and make value added improvements to the supply chain, which resulted in an increase in concession incomes from $2.8 million in 2003 to $5.8 million by 2008 with harvest volumes only increasing by 5 percent (Rosales 2010).

Since the establishment of the reserve, the main drivers of deforestation in the MUZ are primarily the conversion of forestland to agriculture and cattle ranching, much of which can be tied to illegal drug trafficking and organized crime (McSweeny et al. 2014; Hodgdon et al. 2015; Devine et al. 2020). Areas along the road that runs north through the MUZ to the community of Carmelita have experienced the greatest forest cover loss, in part due to year-round road access which further facilitates illegal timber poaching and land clearing for ranching and subsistence farming (Hodgdon et al. 2015). While we cannot completely capture these unobservable factors in the model, we include variables that are related to these deforestation drivers such as distance to the nearest road, distance to the nearest clearing, and distance to the forest edge. Additionally, we compare forest cover loss in the concession areas with a control area of forest in the MUZ that is not under any form of management. To ensure that forest pixels in the concessions are similar to the control areas, we match each type of concession group (industrial, nonresident, long-inhabited, and recently-inhabited) separately on a number of covariates such as distance to forest edge, population centers, and roads as well as geographic features such as elevation, slope, and rainfall. A more detailed discussion of the data and methods is provided below.

To examine the potentially differential impact of the two mechanisms of certification, sustainable management practices and specialized market access, we analyze changes in deforestation at the time the concession officially becomes FSC certified, compared to the prior years after the concession was established and had started to implement their sustainable management plan, but before it was officially certified to see if the added benefit of increased market access and price premiums for certified timber result in additional reductions in forest cover loss. One caveat to this analysis is that given data limitations, land use data is not available for all of the concessions prior to becoming fully certified so we are not able to assess the impact of increased market access for all concession types. Furthermore, the data used for this analysis is from 2001 to 2017 (Hansen et al. 2013), but by 2005 all concessions were FSC certified, so the number of years prior to official certification is limited, and in some cases, the concession was already FSC certified by the first year of observation (see Table 1).

Data and Methodological Approach

The data used for this analysis comes from the multiple-use zone (MUZ) of the MBR. The MUZ is almost 780,000 hectares (38 percent of the total MBR) and contains the community and industrial concessions, which make up the majority of the area (67%). The remaining areas of the MUZ comprise the control regions for this study (see Figure 2). The forests in the control areas are adjacent to the concessions and have similar flora and fauna. These areas also face similar threats to forest cover loss, such as illegal logging and land clearing for agriculture and cattle ranching (Radachowsky et al., 2012; Hodgdon et al., 2015). These areas are not under a formal management plan (Hughell and Butterfield, 2008), but are still theoretically protected since they are within the MUZ and harvesting timber in these areas is considered illegal. Two regions in the control area were actually granted community forest concessions in 2022 (Mesoamerican 2021). These areas were not under the same contracts from 2001 to 2019 as the community concessions described in Table 1, but this suggests that these are suitable control areas since ultimately, they were also selected for concession management. The core zone is excluded from the analysis since it is designated for strict protection and human settlements, farming, and cattle ranching are prohibited in this zone (Hughell and Butterfield, 2008; Rosales 2010). The buffer zone is also excluded since it contains titled land and clearing forest is a legal option for households.

For this analysis, we construct a geospatial panel dataset to estimate the effects of certified concession status on deforestation from 2001 to 2017, refined by the percent tree cover from the year 2000 using a 25% threshold to define forests (Sexton et al., 2016). By using the threshold, we classified the 2000 percent tree cover layer into forest and non-forest and use the latter to filter annual deforestation events that took place on cells that were not forested in 2000. Because of the high local inaccuracy of the geospatial data, we exclude reforestation from our analysis (Hansen et al., 2013). We then randomly sampled 30m by 30m points over the entire MBR by first using a grid with 100m by 100m cells and overlaying the grid with the reserve boundaries in ArcGIS and dropped plots where grid lines on the map did not cross. The original sample size was about 20 million pixels and an approximately equal proportion of pixels was selected from each concession and the control region. The purpose of the grid sampling is to help control for spatial autocorrelation by ensuring that we are not matching non-concession plots that are too close to concession plots (Blackman, 2015).

To further preprocess the data and ensure covariate overlap between the treatment and control groups (e.g., Ho et al., 2007), we match forest pixels from the concessions with forest areas in the control regions, which are the non-concession, multiple-use zone areas of the MBR, based on a number of covariates (see Table 2). The matching model utilized for this analysis is a propensity score nearest neighbor matching model with replacement. We match each concession group (industrial, nonresident, long-inhabited, and recently-inhabited) separately to ensure the treated pixels are analyzed with the most similar control group pixels.[3] Estimated via a logit, the propensity score is the predicted probability that a sample unit is under concession management.

[3] Results of the matching analysis are available upon request.

Descriptive statistics for the concession and matched control group MBR pixels are shown in Table 1A in the Appendix.

Table 2. Variable Names and Descriptions

Variable name	Description
Forest loss	This variable is constructed from the Global Forest Change data set described in Hansen et al. (2013). It represents the forest loss in each year from 2001 to 2019. The variable is equal to 1 if the 100m by 100m pixel was deforested in a given year. A pixel is "deforested" if the amount of forest on the pixel drops below 25%.
Initial (2000-level) biomass	This variable is constructed from the Aboveground live woody biomass density layer from Global Forest Watch. The data is at a 30-meter resolution for the year 2000.
Current Concession	This variable is equal to 1 if the 30m by 30m pixel is under concession management and 0 if it is not. The separate variables for each type of concession used in this analysis are nonresident, long-inhabited, and recently-inhabited.
Concession classification (nonresident, recently-inhabited, industrial, long-inhabited)	Binary variables for whether the pixel is in each classification. A pixel will only belong to one concession type or the non-concession multiple use zone.
Distance to road	Indicates the distance of each pixel to the nearest road in meters.
Distance to archaeological site	Indicates the distance of each pixel to the nearest archaeological site in meters. The archaeological sites considered are el Mirador, Tikal, and Yaxha-Nakum-Naranjo, which are the three most visited archaeological sites in the Maya Biosphere Reserve.
Soil Nutrients	An index for the amount of nutrients in the soil ranging from 1, meaning no or few limitations, to 7, meaning water bodies, or non-soil areas.
Elevation	Taken from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM), which is a product of METWe and NASA. The resolution is 70m and the unit is meters with 0 meters being at sea level.
Air Temperature	The National Oceanic and Atmospheric Administration's raster dataset on annual air temperatures is about 0.5° by 0.5° and is measured in Celsius.
Precipitation	Represents the average annual rainfall in millimeters for each pixel for each year from 2001 to 2019.
Biodiversity	Taken from Jenkins (2015), this variable represents the total number of mammal and bird species observed for each pixel.
Distance to eastern edge	Represents the distance from the pixel to the eastern edge of the MBR is meters.

Distance to western edge	Represents the distance from the pixel to the western edge of the MBR is meters.
Distance to northern edge	Represents the distance from the pixel to the northern edge of the MBR is meters.
Distance to buffer zone	Represents the distance from the pixel to the buffer zone of the MBR in meters. The buffer zone is located on the southern border of the MBR and is home to towns and households with a variety of professions.
Distance to forest edge	Represents the distance from the pixel to the edge of the nearest forested area in meters. Because the forest edge is changes as additional pixels are deforested in the MBR, this value varies annually.
Distance to nearest city	Represents the distance from the pixel to the nearest town or city in meters.
Distance to the nearest clearing	Represents the distance from the pixel to the nearest forest clearing in the year 2000 in meters.

Note: Unless otherwise mentioned, the data are at the 30 by 30-meter pixel resolution. Observations that are non-soil areas or bodies of water were dropped from the analysis.

Empirical Model Specification

The main model specification for this analysis is a random effects panel estimator with year and concession-level fixed effects with matching to preprocess the sample (Ho et al., 2007; Imbens and Wooldridge, 2009; Ferraro & Miranda, 2017). One limitation of this analysis is that we rely on a random effects estimator, which assumes the control variables and the error term are not correlated. However, we are unable to use the Hausman test to determine whether the random effects estimator is the appropriate model because we cannot estimate the results of a fixed effects model due to the concessions in the MBR being established before the deforestation data begins. Thus, to improve the robustness of our model, we preprocess the sample using propensity score, nearest neighbor matching methods to ensure covariate overlap between the treatment and control groups, which mitigates the effects of selection and omitted variable bias. Our model includes four separate treatment dummies for each of the three types of community concessions (nonresident, long-inhabited, and recently-inhabited) and the industrial concessions. In addition to whether the pixel (30m by 30m area of land) is under concession management, we control for distance to the nearest road, distance to the nearest archaeological site, soil nutrients, elevation, biodiversity presence, distance to nearest clearing, 2000-level woody biomass levels, and precipitation levels. Distance to the nearest road and distance to the nearest archaeological site are proxies for accessibility which would likely increase the probability a pixel is deforested. Soils that are more acidic are more likely to not foster tree growth; pixels at higher elevations are less likely to be deforested through slash-and-burn agricultural methods; and pixels that receive higher levels of precipitation are more likely to foster forest growth. We include distance to the edges of the reserve and the buffer zone as an additional proxy for how remote the forest pixel is and its potential proximity to illegal cattle ranching that is related to narco-drug trafficking in the reserve, which has been found to take place in the western portion of the reserve and along the road to *Carmelita* in the MUZ (Hodgdon et al., 2015; Devine et al., 2020).

We can write the main model as: [4]

$$y_{igt} = \alpha_0 + \alpha_t + \gamma * treat_{igt} + \beta x_{igt-1} + \partial z_{gt-1} + u_{0ig} + u_{1ig} * t + \varepsilon_{igt} \quad (1)$$

In equation 1, *i* indicates the pixel id, g the concession or forest patch pixel *i* is selected from, and *t* is the year of observation. The variable y_{igt} is the individual level outcome (e.g., whether pixel *i* in concession or forest patch g got cleared in a given year t), α_0 is a common intercept, α_t is a year fixed effect, and $treat_{igt}$ is a dummy variable indicating the whether the pixel was in one of the four treatment groups (industrial, nonresident, recently-inhabited, or long-

[4] Note, this is similar to Wooldridge 2007 pp4-7

inhabited) in year t. The x_{igt-1} is a one-year lagged set of pixel-level time-varying covariates[5] (e.g. precipitation, temperature) and z_{gt-1} is a one-year lagged set of concession/forest patch-level covariates (e.g. population). We use lags for this analysis because we suspect that the effect of these variables on forest loss does not occur immediately after a change in the value of each variable. $u_{1ig} * t$ is a random concession/forest patch effect that is a function of the year; u_{0ig} is a random constant mean effect, and ε_{igt} is an idiosyncratic error. One limitation to this analysis is that the random effects estimator assumes the control variables and the error term are not correlated. However, we are unable to use the Hausman test to determine whether the random effects estimator is the appropriate model because we cannot estimate the results of a fixed effects model due to the concessions in the MBR being established before the deforestation data begins. While we cannot show that the random effects estimator is the most efficient estimator with the Hausman test, we preprocessed the sample using propensity score, nearest neighbor matching methods to ensure covariate overlap between the treatment and control groups, which mitigates the effects of selection and omitted variable bias.

In a separate analysis, we use a fixed effects model to estimate the impact of obtaining official FSC certification on forest loss within the concession areas based on the lag in timing between gaining concession status and becoming officially certified. This is to see if the added benefits that come with official certification (e.g. specialized market access and price premiums) further contribute to reduced forest cover loss beyond the implementation of sustainable management practices, which were initiated when the concession was first established. The results then show us the value-added effect of FSC certification status on deforestation beyond

[5] Because we are going to use annual data and cannot determine when within a given year deforestation occurred relative to certification etc for that year, it makes sense to use lagged values and do contemporaneous ones (no time lags) as a robustness check.

the sustainable forest management efforts implemented by the concessions. For a community to gain concession status, they had to become FSC certified within three years of being granted a concession. The 14 concessions formed between 1998 and 2002 and the gap in years between gaining concession status and becoming certified ranges from zero to five years. Using this gap in timing, we determine the effect of FSC certification using a fixed effects panel model (Equation 2). The model is estimated only for concession pixels with FSC certification as the covariate of interest.

$$y_{ikt} = \alpha_i + \alpha_t + \gamma * FSC_{ikt} + \beta x_{ikt} + \varepsilon_{ikt} \quad (2)$$

The variable y_{ikt} is the individual level outcome (e.g., whether pixel *i* in concession *k* got cleared in a given year t), α_i is the pixel fixed effect, α_t is a year fixed effect, and FSC_{ikt} is a dummy variable indicating the whether the pixel was FSC certified in year *t*. The x_{ikt} is a set of pixel-level time-varying covariates (e.g. precipitation, temperature, distance to forest edge), and ε_{ikt} is an idiosyncratic error.

Results

Overall, the results indicate that community concession management coupled with FSC certification does reduce deforestation relative to non-concession multiple-use zone areas of the MBR, though this impact is heterogeneous across the three different types of community concessions. Figure 3 shows the different general deforestation trends of the nonresident, industrial, recently-inhabited, and long-inhabited concessions compared to the multiple use zone not under concession management. The long-inhabited and nonresident concessions reduced deforestation by 0.8 and 1.2 percent annually respectively, relative to their matched control groups (see Table 3). For recently-inhabited concessions, however, the effect of being under concession management increased deforestation by about 0.7 percent annually. In comparison, industrial concession management decreased deforestation by about 0.7 percent annually, outperforming only the recently-inhabited community concessions. This suggests that community-based forest management can be just as effective, if not more so, than private industrial concessions, which comprise the majority of FSC managed concessions worldwide (FSC, 2016).   The effects of the control variables on deforestation vary among concession types due to differences in their values across concessions. Descriptive statistics for the control variables are shown in Table 2A in the Appendix.

Figure 3. Annual MBR Forest Loss (%) 1990 to 2017

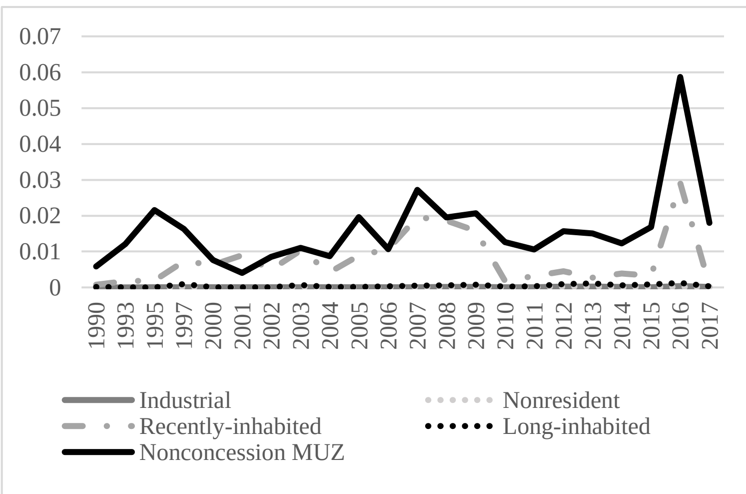


Table 3. Random Effects Results for FSC-Certified Concession Management by Type

	All Concessions	Industrial	Recently Inhabited	Nonresident	Long Inhabited
Concession	-0.01002***	-0.00725***	0.00676***	-0.0115***	-0.00810***
	(9.78E-05)	(0.000152)	(0.00121)	(8.81e-05)	(0.000249)
Air temperature					
	-0.00125***	0.00148***	-0.00758***	-0.00139***	-3.77e-05
	(0.000052)	(0.000170)	(0.00210)	(8.09e-05)	(0.000112)
Precipitation	6.72E-07***	2.42e-06***	7.53e-06***	3.97e-07**	4.80e-07

	(1.34E-07)	(3.45e-07)	(2.77e-06)	(1.55e-07)	(4.37e-07)
Distance to the eastern edge	6.34E-08***	-1.18e-07***	3.27e-06***	4.65e-08***	-2.18e-07***
	(5.41E-09)	(1.93e-08)	(3.26e-07)	(9.04e-09)	(1.88e-08)
Distance to the western edge	8.89E-08***	-4.09e-10	3.10e-06***	9.67e-08***	-2.11e-07***
	(5.42E-09)	(2.23e-08)	(3.25e-07)	(9.39e-09)	(1.95e-08)
Distance to the northern edge	7.82E-08***	3.66e-07***	5.58e-06***	-6.34e-08***	2.13e-07***
	(1.22E-08)	(3.35e-08)	(6.23e-07)	(1.43e-08)	(4.85e-08)
Distance to the forest edge	-7.09E-08***	-1.38e-07***	-5.06e-06***	-2.35e-08***	-2.44e-07***
	(5.48E-09)	(1.21e-08)	(2.16e-07)	(6.16e-09)	(1.92e-08)
Distance to the buffer zone	1.25E-08	1.41e-07***	4.63e-06***	-1.98e-07***	1.04e-07**
	(1.20E-08)	(4.04e-08)	(5.22e-07)	(1.32e-08)	(4.13e-08)
Distance to the nearest road	-8.95E-08***	-5.72e-08***	1.25e-06***	2.27e-08***	-7.59e-08***
	(5.46E-09)	(1.86e-08)	(1.59e-07)	(7.62e-09)	(1.39e-08)
Distance to the nearest archaeological site	5.07E-08***	2.65e-07***	1.52e-06***	1.10e-07***	2.04e-07***
	(4.06E-09)	(1.35e-08)	(1.83e-07)	(4.55e-09)	(1.80e-08)
Elevation (m)	1.52E-06***	-1.45e-05***	-3.20e-05***	6.28e-06***	1.20e-05***
	(3.72E-07)	(1.60e-06)	(1.11e-05)	(4.54e-07)	(8.56e-07)
Biodiversity presence	-3.4E-05***	3.38e-05*	0.000727***	-3.48e-06	0.000215***
	(6.11E-06)	(1.87e-05)	(0.000158)	(7.02e-06)	(2.12e-05)
2000-level biomass	-6.5E-05***	-5.02e-05***	-0.000163***	-4.02e-05***	-7.03e-05***
	(5.23E-07)	(1.21e-06)	(5.60e-06)	(6.97e-07)	(1.23e-06)
Soil toxicity	-0.00018***	0.000158	-0.00568***	7.58e-05	0.000990***
	(3.66E-05)	(0.000109)	(0.000532)	(7.73e-05)	(6.70e-05)
Distance to the nearest city center	-8.71E-09*	-3.16e-07***	2.91e-08	-1.57e-07***	-1.74e-07***
	(4.52E-09)	(1.07e-08)	(1.02e-07)	(5.97e-09)	(1.27e-08)
Distance to the nearest clearing	-3.39E-08***	-5.88e-08***	2.78e-06***	1.04e-08	-1.06e-07***
	(6.36E-09)	(1.67e-08)	(2.56e-07)	(7.20e-09)	(1.93e-08)
Long-inhabited	0.000616***	N/A	N/A	N/A	N/A
	(3.96E-05)	N/A	N/A	N/A	N/A
Recently-inhabited	0.007393***	N/A	N/A	N/A	N/A

	(8.84E-05)	N/A	N/A	N/A	N/A
Industrial	0.000381***	N/A	N/A	N/A	N/A
	(4.54E-05)	N/A	N/A	N/A	N/A
Constant	0.043935***	-0.0570***	-1.090***	0.0409***	-0.0593***
	(0.0032848)	(0.0108)	(0.132)	(0.00427)	(0.0110)
Observations	5,128,288	1,380,944	292,608	2,282,736	1,448,768

Note: Results represent annual effects of each variable on forest loss. Observations are 30m by 30m pixels. Standard errors clustered at the concession level and are in parenthesis. Unmatched pixels were dropped from the analysis.
*** p<0.01.
** p<0.05.
*p<0.10.

The results for the long-inhabited and nonresident concessions are consistent with previous research by Fortmann et al. (2017). They show that all three types of concessions reduced deforestation relative to a matched control area in the MUZ. While the results regarding the recently-inhabited concessions in our analysis are contrary to these previous findings, there are some important differences between the two studies. Fortmann et al. (2017) used a different forest cover dataset that spanned the years 1986 to 2008, but was not based on annual data. They found that the recently-inhabited concessions reduced deforestation relative to the matched control group, though deforestation in these concessions was still significantly higher than the other two concession types. This difference may be attributed to the fact that all four concession communities were included in the analysis. In comparison, this paper extends the period of analysis almost another decade to the year 2017, but starts the analysis in the year 2001 based on the availability of the Hansen land-use data. Our analysis also excludes the cancelled concessions, thus the recently-inhabited concession results are based on one concession, *Cruce a la Colorada*, which has also struggled with noncompliance and previously had their certification suspended, though they are currently up to date on their certification. Overall, we find that while the recently-inhabited concessions may have been effective at reducing deforestation through 2008 (Fortmann et al., 2017), community concession management did not continue to reduce forest loss compared to the matched non-concession areas of the MUZ through 2017.[6] See the Discussion section below for further analysis.

FSC Treatment on Concessions Results

To examine the value-added impact of specialized market access and price premiums for certified wood on forest loss, we test the effect of becoming FSC certified on concession areas only. The results from the fixed effect regressions with the FSC treatment variable indicate that becoming FSC certified and its associated benefits, led to a small, but significant reduction in deforestation. The air temperature, distance to the forest edge, and precipitation coefficients are also small, which we suspect is partially due to the landscape of the MBR being fairly similar among the concessions. On average, the reduction in FSC certified concessions was about 0.019 percent across all concessions (see Table 4[7]). We attribute this to higher incomes due to increased market access for certified wood (Rosales 2010), which may lead to greater incentives for monitoring and protecting the forest if it is more valuable. However, since there were only a few years during the study period where some concessions did not receive FSC certification, which is a requirement for maintaining concession status, it is likely that these results are not conclusive and more research is needed to better understand the mechanisms by which forest certification schemes reduce deforestation.

Table 4. Results of the Fixed Effects model for the FSC Treatment on Concessions Results

	All Concessions	**Nonresident**	**Industrial**	**Recently Inhabited**
FSC	-0.000189***	0.000108***	-9.27E-05	0.005098
	(0.0000379)	(0.0000283)	(0.0000593)	(0.009088)

[6] The results from an Ordinary Least Squares Robustness check show similar effects. The results are shown in Table 3A in the Appendix.
[7] The results from a Random Effect model robustness check show similar effects. The results are shown in Table 4A in the Appendix.

Air temperature	0.0006759***	-0.0000644	0.0000553	-0.00303
	(0.0000813)	(0.0000734)	(0.0001241)	(0.043671)
Precipitation	-2.48E-07***	5.51E-08	3.51E-07***	-2.13E-05**
	(7.69E-08)	(5.92E-08)	(1.43E-07)	(8.88E-06)
Distance to forest edge	-3.04E-08***	-3.11E-08***	-3.56E-08***	-7.95E-06***
	(3.99E-09)	(3.01E-09)	(5.65E-09)	(4.99E-07)
Constant	-0.016655***	0.0018412	-0.001616	0.142216
	(0.0020892)	(0.0019031)	(0.0031401)	(1.148517)
Observations	4,835,680	2,190,480	1,288,688	200,352

Note: Results for long-inhabited concessions are unavailable because they were FSC certified for the entire analysis period. However, the long-inhabited observations are accounted for in the “All Concession” results. Results represent annual effects of each variable on forest loss. Observations are 30m by 30m pixels. Standard errors are in parenthesis.

The results for nonresident concession are smaller in magnitude, but positive and significant, which indicates that receiving official FSC certification increased annual forest loss by about 0.01 percent. These results are somewhat limited since the number of years of observation prior to certification are few. Though, it is possible that, once the sustainable harvesting practices were officially implemented in nonresident concessions, deforestation increased slightly. However, the results shown in Table 4 indicate that nonresident concession management decreased forest loss by 1.15 percent annually, which suggests that the sustainable management plan requirement, rather than the market access that comes with official FSC certification status, is the main driver for reducing forest cover loss in nonresident concessions. Although the magnitude of the results is small, we believe the overall findings indicate that the sustainable forest management practices required for certification are effective at reducing deforestation. Given our limited analysis, the additional benefits of increased market access and price premiums that come from becoming officially certified are unclear, but these results suggest a small additional impact on reducing deforestation.

Discussion

Overall, we find that devolving management authority to local communities with proper structures in place (i.e. certification) can have positive long-term results, but community characteristics also play a role in being able to successfully manage and maintain forest certification. In this section, we first discuss the results from our analysis and provide some context that could explain our findings. We then provide a broader discussion on what our results imply for CFM in other regions of the world and how certification could be a potential policy option that could help overcome some of the challenges and limitations faced in forest dwelling communities in developing country contexts.

Our findings suggest that forest certification in community managed forests can be just as effective as certified industrial concessions at reducing forest cover loss. In fact, the long-inhabited concession communities had lower rates of deforestation compared to the matched control group relative to the industrial concession rates. The more remote nonresident concessions had similar rates of reduced deforestation as the industrial ones. These results may be due to the fact that community concession members receive a share of the profits earned by selling FSC-certified forest products and concession members have been shown to earn higher annual household incomes than non-concession members (Bocci et al., 2018). To compare, employees at industrial concessions earn a wage of about 10 to 12 U.S. dollars per day regardless of the concession's profits. In contrast, concession members who receive dividends often earn about 26 U.S. dollars per day, which implies that the community concession model may provide more of an incentive to maintain sustainable management efforts, relative to privately managed industrial concessions. However, although concession members who receive dividends tend to earn more per day on average, these dividends are often not distributed evenly with some concession members not receiving any and some receiving over $30 U.S. dollars per day. Some community concessions do not distribute dividends, but instead, donate profits from sustainable forestry back into the community (Bocci et al. 2018; Radachowsky et al. 2012).

Spatial factors also likely played a role in the higher rates of deforestation in the recently-inhabited concessions for a number of reasons (Radachowsky et al., 2012). By their nature, these concession communities were comprised of migrants that settled in areas that were already experiencing population growth, which often is accompanied by increased deforestation pressures. This is likely augmented by the fact that migrants moving in the area have little to no previous forest experience. As a result, granting concessions to such communities which provides them with legal rights to access the forest could in fact lead to *more* deforestation, relative to matched non-concession areas. Recently-inhabited concessions also tended to be smaller in size compared to other concessions (Radachowsky et al. 2012) and thus their potential for income generation and the subsequent distribution of dividends and in-kind benefits from concession profits may have been more limited, further reducing their incentive for maintaining the forest. Finally, the presence of external pressures for cattle ranching and drug trafficking likely influenced the success, or lack thereof, of these concessions. While we control for distance to each MBR border, distance to the nearest road, and distance to the nearest forest clearing as proxies for these external pressures, there are likely other factors that we are unable to control for in the matching analysis. For example, Radachowsky et al. (2012) recount an incident in which the members of a recently-inhabited concession, *La Colorada*, reportedly fled the area after selling their land rights to a cattle rancher that was rumored to have ties to organized crime. The concession was canceled soon after in 2008.

Despite the results for the recently-inhabited concessions in terms of increased forest cover loss relative to a matched control area, we find that when comparing *Cruce a la Colorada* to the other recently-inhabited concessions that were canceled, they actually outperformed these former concession areas in terms of reduced deforestation. Figure 4 shows a graph of deforestation trends for the recently-inhabited and canceled concessions that demonstrates that the canceled concessions had higher rates of deforestation than *Cruce a la Colorada*, the remaining active recently-inhabited concession. Average annual forest loss from 2001 to 2017 was 0.008 percent in *Cruce a la Colorada* compared to forest loss of 0.018 percent annually averaged across all previously canceled concessions over the same time period (see Table 5). This suggests that despite having higher deforestation rates compared to other concessions in the MBR, *Cruce a la Colorada* still managed to reduce deforestation relative to what would have happened had it not maintained its concession status but instead was canceled along with the other concessions made up of recent migrant communities. Devine et al. (2020) further claim that "the experience of *Cruce a la Colorada* illustrates that strengthening local governance institutions in the form of community-based resource management makes protected areas more resilient to narco-land grabs." (p.8).

Figure 4. Recently-inhabited and canceled concession forest loss (%)

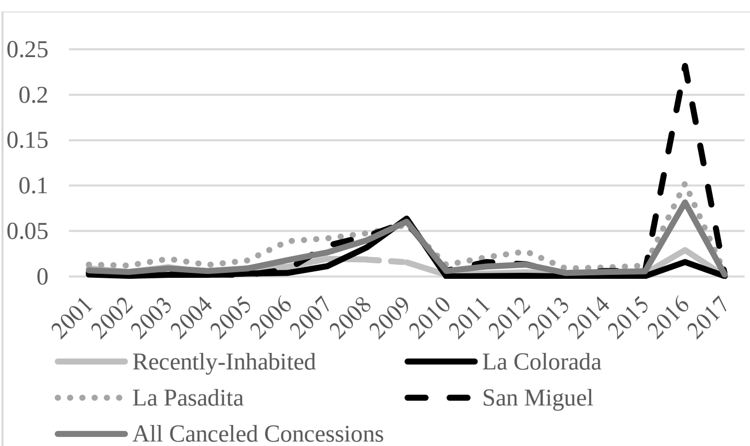


Table 5. Recently-inhabited and canceled concession deforestation rates.

Annual Forest Loss	Cruce a la Colorada	La Colorada	La Pasadita	San Miguel	All Canceled Concessions
2001	0.0089	0.0022	0.0133	0.0045	0.0069
2002	0.0049	0.0009	0.0120	0.0007	0.0052
2003	0.0103	0.0017	0.0196	0.0041	0.0090
2004	0.0042	0.0019	0.0126	0.0024	0.0061
2005	0.0089	0.0034	0.0178	0.0019	0.0088
2006	0.011	0.0038	0.0390	0.0077	0.0181
2007	0.0196	0.0114	0.0420	0.0338	0.0267
2008	0.0186	0.0321	0.0476	0.0444	0.0399
2009	0.0157	0.0638	0.0567	0.0598	0.0604
2010	0.0018	0.0001	0.0127	0.0066	0.0060
2011	0.0031	0.0005	0.0214	0.0160	0.0109
2012	0.0045	0.0007	0.0277	0.0135	0.0131
2013	0.0027	0.0002	0.0090	0.0031	0.0041
2014	0.0039	0.0002	0.0100	0.0061	0.0049
2015	0.0033	0.0005	0.0119	0.0058	0.0057
2016	0.0291	0.0158	0.1023	0.2317	0.0816
2017	0.0006	0.0004	0.0042	0.0018	0.0021
Average annual forest loss	0.0089	0.0082	0.0271	0.0261	0.018

Note: Averages for the "All canceled concessions" results are weighted by concession size.

The long-term sustainability of community forest management has been an ongoing question. These results suggest that community concession management combined with forest certification can be a successful approach in the long-term. In fact, as of 2022, five of the concessions[8] have had their contracts renewed for another period of 25-years (Mesoamerica 2021). It should also be noted that two of the control regions in the study applied for and were awarded concessions in 2022[9]. They completed the bidding process and documentation for the granting of concession status was prepared in 2019 (USAID 2019) after the period of analysis for this study, however it is likely that communities in these areas were managing the forests in preparation for being granted concessions for a number of years toward the latter end of our study period. If this is the

[8] The five concessions that have been renewed as of 2022 are *Carmelita*, *Las Ventanas, San Andres, Chosquitán*, and *Suchitecos*.
[9] The two control regions that were granted concessions are *La Colorada – El Molino* and *San Bartolo* (Mesoamerica 2021).

case, then it would suggest that our results actually underestimate the impact of concession management and certification on forest loss since areas in the control group were also being protected.

Another factor that has likely contributed to the long-term success of these community concessions is the creation of FORESCOM under ACOFOP, which has allowed the member concessions to coordinate resources and technical support and gain entrance into larger niche markets that individual concession might otherwise not be able to access due to low volume and/or lack of resources. This could provide a model for other smallholder community groups managing the forest as well, where one criticism of forest certification is that it favors large-scale operations over smaller ones due to their ability to capitalize on economies of scale (Auld et al. 2008). By certifying smaller community groups under one umbrella organization, communities are able to reduce their costs and combine their timber output to allow for greater market integration in addition to the benefits gained from sharing technical and administrative expertise across groups creating a more formalized network of support among the communities (Carrera et al. 2006).

We believe that *mandatory* certification coupled with community forest management could be a viable policy approach to reduce forest cover loss in community managed forests across the tropics and a similar model could be considered for future community-based forest management systems. This would be a departure from more traditional approaches where certification has mainly been a voluntary enterprise for privately managed forests (FSC 2016). Furthermore, in the absence of strong local governance, devolving forest rights to local communities combined with mandatory certification could be a way to provide structure and guidance for communities to manage the forests sustainably. However, we are not suggesting that certified CFM is a one size fits all panacea for reducing deforestation and it may be more suitable for certain types of community groups that have previous forest experience and long-standing ties to the region. Thus certification could be beneficial in similar types of forest dwelling communities in other parts of the world such as Bolivia where CFM became popular in the 1990s and a number of indigenous community forestry enterprises are in operation, or in Brazil, where efforts to engage local communities in sustainable timber extraction have been made but the communities have struggled to develop management plans and navigate the administrative and technical aspects at a commercial scale (Cronkleton, Bray & Medina 2011). Mexico provides another example where CFM combined with certification could alleviate some of the challenges the communities have faced. Giving communities the tools and resources to manage the forests for commercial timber themselves, as opposed to external concessionaires, would put the power back in the hands of the communities and allow them to gain the benefits of engaging in certified timber harvesting (Baynes et al. 2016). Additionally, smallholder groups in Mexico could join together to be certified under one body, which could alleviate some of the challenges they face regarding insufficient timber resources (Antinori and Rausser, 2007; Baynes et al. 2016) and limited profits from timber sales (Mitchell 2005; Baynes et al. 2016).

An additional benefit of combining CFM with certification in other countries that have or are in the process of devolving forest management rights to local communities is the added legitimacy certification brings (Carrera et al. 2006). In places where the government or even environmental conservationists might be skeptical about the ability of local communities to manage the forest sustainably, certification requirements could provide assurances that the communities will have appropriate guidelines and processes to manage the forest and NGOs will be able to more easily provide assistance in the certification process if there is a common framework being implemented across different regions.

One question that still remains is whether certified community forest enterprises are financially viable since certification comes at a cost and smallholder participants have often struggled more with being financially sustainable (Humphries, et al. 2012). The communities in the reserve have worked to overcome some of the financial challenges through joining together to form ACOFOP, which serves to both advocate for the community concessions as well as cost share to reduce the financial burden on individual community groups through collectively investing in capital resources (Carrera et al. 2006; Millner et al. 2020). However, the concessions initially relied heavily on NGOs to provide financial, technical, and administrative assistance to develop their management plans and become certified (Carrera et al. 2006) and since then many groups have still struggled to get loans from banks and become financially secure (Butler 2021). External support would most likely be necessary if certification became a requirement for other communities engaged in CFM and more research on the long-term viability of certified community forest groups after external support and funding has been withdrawn is still needed.

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Appendix

Table 1A. Concession and Control Group Summary Statistics

	Concession Area Mean	**Non-Concession MUZ Mean**
Annual Forest Loss	0.05%	1.10%
Air temperature (Celsius)	25.44	25.66
Precipitation (meters)	1538.76	1639
Distance to eastern edge (meters)	63936.63	96455
Distance to western edge (meters)	126342.6	93624.1
Distance to forest edge (meters)	3830.78	1359.51
Distance to northern edge (meters)	34161.22	40456.6
Distance to buffer zone (meters)	40204.94	28361.45
Distance to nearest road (meters)	3244.1	3415.08
Distance to nearest archaeological site (meters)	52979.65	53649.45
Elevation (meters)	229.16	174.66
Biodiversity Presence	415.39	415
Initial biomass	131.34	91.54
Soil acidity	7.43	7.12
Distance to nearest city (meters)	6103.63	9904.88
Distance to nearest clearing (meters)	3615.74	1795.9

For a description on these variables, see Table 2. The Non-Concession Multiple Use Zone mean is for the matched sample.

Table 2A. Descriptive Statistics for Control Variables by Concession Type

	Recently-inhabited			
Variable	Mean	Std. Dev.	Min	Max
Air Temperature	25.96186	0.41698	24.6	27.1
Precipitation	1583.992	221.011	1159.964	2232.192
Distance to eastern edge	87895.99	5053.375	78298.44	98619.2
Distance to western edge	106107.3	4900.424	95609.38	115795.9
Distance to northern edge	44215.26	3352.23	37481.63	50594.81
Distance to the forest edge	1680.26	1850.045	6.900206	8749.647
Distance to the buffer zone	27738.39	3544.472	20745.52	35531.1
Distance to the nearest road	1931.413	1894.776	0.148388	8240.083
Distance to the nearest archarological site	37028.84	3430.741	29573.45	43245.32
Elevlation (m)	271.0533	37.45046	162	346
Biodiversity presence	415.1526	1.981901	413	419
200-level biomass	92.27716	54.40846	0	177.3923
Soil Toxicity	7.72843	0.553578	6.6	8
Distance to the nearest city center	6512.801	2949.693	73.47958	13591.55
Distance to the nearest clearing	1615.861	1551.989	9.091174	6646.033
	Long-inhabited			
Variable	Mean	Std. Dev.	Min	Max
Air Temperature	25.43451	0.515645	24.3	27.1

Precipitation	1514.026	227.7455	1007.052	2225.933
Distance to eastern edge	65746.16	25100.22	29858.06	110584.2
Distance to western edge	126581.1	23844.19	83506	164615.1
Distance to northern edge	31655.25	9818.172	14930.9	53353.2
Distance to the forest edge	3213.2	2214.309	4.110819	15118.32
Distance to the buffer zone	41949.84	9564.182	23944.21	61286.71
Distance to the nearest road	4196.572	3336.407	0.069796	14474.89
Distance to the nearest archarological site	52263.01	9424.347	30551.74	68710.86
Elevlation (m)	225.804	60.05631	99	429
Biodiversity presence	413.0533	4.349149	405	422
200-level biomass	131.9971	26.67315	0	186.282
Soil Toxicity	7.446565	0.687042	6.4	8
Distance to the nearest city center	6333.65	2965.527	41.88673	13892.64
Distance to the nearest clearing	3395.136	2233.643	4.110819	11588.06

Nonresident

Variable	Mean	Std. Dev.	Min	Max
Air Temperature	25.57347	0.482346	24.3	27.1
Precipitation	1569.68	256.2348	981.4832	2276.399
Distance to eastern edge	45177.4	45108.34	1.399259	127457.9
Distance to western edge	141669.1	40426.94	66809.3	194036.7
Distance to northern edge	41142.45	14552	16347.39	74568.35
Distance to the forest edge	4255.911	3200.257	6.900206	27330.25
Distance to the buffer zone	36405.2	14402.73	7964.713	67630.36
Distance to the nearest road	3513.812	2814.589	0.009043	15077
Distance to the nearest archarological site	49708.82	12580.94	18704.35	76298.73
Elevlation (m)	206.4559	54.93128	72	367
Biodiversity presence	420.3936	8.990978	406	442
200-level biomass	132.7042	23.43778	0	204.9492
Soil Toxicity	7.163345	0.404871	6.4	8
Distance to the nearest city center	5662.21	3538.986	12.8537	18974.11
Distance to the nearest clearing	4129.461	2670.879	8.04166	12329.42

Industrial

Variable	Mean	Std. Dev.	Min	Max
Air Temperature	25.1442	0.455079	24.3	27.1
Precipitation	1505.193	220.3261	1017.805	2109.442
Distance to eastern edge	90193.38	24343.09	57196.63	130327.1
Distance to western edge	103186.1	23659.77	63904.93	136893.9
Distance to northern edge	23369.45	16435.19	0.236029	54057.04
Distance to the forest edge	4092.577	2895.368	4.00974	18979.79
Distance to the buffer zone	46765.09	11453.24	23033.74	67717.04
Distance to the nearest road	1987.144	1658.673	0.077344	8528.937

Distance to the nearest archarological site	61773.56	19305.29	27781.38	94872.99
Elevlation (m)	264.7532	79.94169	111	411
Biodiversity presence	409.3893	7.302575	399	421
200-level biomass	134.3871	23.68612	0	189.8914
Soil Toxicity	7.833309	0.315968	6.6	8
Distance to the nearest city center	6548.193	3494.443	25.34218	17298.67
Distance to the nearest clearing	3285.66	2127.787	4.00974	11764.25

Table 3A. OLS Results for the effect of FSC-certified concession management on Annual Forest Loss

	All Concessions	Industrial	Recently Inhabited	Nonresident	Long Inhabited
Concession	-0.0089978***	- 0.0072497***	0.0067621***	-0.0114763***	-0.0081017***
	(0.000096)	(0.0001519)	(0.0012098)	(0.0000881)	(0.0002491)
Air temperature	0.0006779***	0.0014839***	-0.0075764***	-0.0013858***	-0.0000377
	(0.0000462)	(0.0001699)	(0.0021006)	(0.0000809)	(0.0001121)
Precipitation	1.03E-07	2.42E-06***	7.53E-06***	3.97E-07***	4.80E-07
	(1.34E-07)	(3.45E-07)	(2.77E-06)	(1.55E-07)	(4.37E-07)
Distance to the eastern edge	1.34E-07***	-1.18E-07***	3.27E-06***	4.65E-08***	-2.18E-07***
	(5.35E-09)	(1.93E-08)	(3.26E-07)	(9.04E-09)	(1.88E-08)
Distance to the western edge	1.14E-07***	-4.09E-10	3.10E-06***	9.67E-08***	-2.11E-07***
	(5.37E-09)	(2.23E-08)	(3.25E-07)	(9.39E-09)	(1.95E-08)
Distance to the northern edge	2.33E-07***	3.66E-07***	5.58E-06***	-6.34E-08***	2.13E-07***
	(1.13E-08)	(3.35E-08)	(6.23E-07)	(1.43E-08)	(4.85E-08)
Distance to the forest edge	-8.82E-08***	-1.38E-07***	-5.06E-06***	-2.35E-08***	-2.44E-07***
	(5.37E-09)	(1.21E-08)	(2.16E-07)	(6.16E-09)	(1.92E-08)
Distance to the buffer zone	2.30E-07***	1.41E-07***	4.63E-06***	-1.98E-07***	1.04E-07***
	(1.11E-08)	(4.04E-08)	(5.22E-07)	(1.32E-08)	(4.13E-08)
Distance to the nearest road	-1.82E-07***	-5.72E-08***	1.25E-06***	2.27E-08***	-7.59E-08***
	(5.01E-09)	(1.86E-08)	(1.59E-07)	(7.62E-09)	(1.39E-08)
Distance to the nearest archaeological site	-2.35E-08***	2.65E-07***	1.52E-06***	1.10E-07***	2.04E-07***
	(3.68E-09)	(1.35E-08)	(1.83E-07)	(4.55E-09)	(1.80E-08)
Elevation (m)	2.72E-06***	- 0.0000145***	-0.000032***	6.28E-06***	0.000012***
	(3.67E-07)	(1.60E-06)	(0.0000111)	(4.54E-07)	(8.56E-07)
Biodiversity presence	-0.0000247***	0.0000338*	0.0007275***	-3.48E-06	0.0002146***
	(6.09E-06)	(0.0000187)	(0.0001584)	(7.02E-06)	(0.0000212)
2000-level biomass	-0.0000734***	- 0.0000502***	-0.0001629***	-0.0000402***	-0.0000703***
	(5.12E-07)	(1.21E-06)	(5.60E-06)	(6.97E-07)	(1.23E-06)
Soil toxicity	0.0002182***	0.000158	-0.0056791***	0.0000758	0.0009903***
	(0.0000362)	(0.0001095)	(0.0005317)	(0.0000773)	(0.000067)
Distance to the nearest city center	1.93E-09	-3.16E-07***	2.91E-08	-1.57E-07***	-1.74E-07***

	(4.50E-09)	(1.07E-08)	(1.02E-07)	(5.97E-09)	(1.27E-08)
Distance to the nearest clearing	-5.79E-08***	-5.88E-08***	2.78E-06***	1.04E-08	-1.06E-07***
	(6.27E-09)	(1.67E-08)	(2.56E-07)	(7.20E-09)	(1.93E-08)
Constant	-0.0283675***	-0.0569899***	-1.089826***	0.0408597***	-0.0592961***
	(0.0030913)	(0.0107982)	(0.1320596)	(0.0042734)	(0.010961)
Observations	5,128,288	1,380,944	292,608	2,282,736	1,448,768

Note: Results represent annual effects of each variable on forest loss. Observations are 30m by 30m pixels. Standard errors clustered at the concession level and are in parenthesis. Unmatched pixels were dropped from the analysis.
*** p<0.01.
** p<0.05.
*p<0.10.

Table 4A. Forest Loss Random Effect Results for FSC Treatment on Concessions

	All Concessions	Nonresident	Industrial	Recently Inhabited
FSC	-0.0000536	0.0001228***	-8.66E-05	0.0104421***
	(0.0000368)	(0.0000272)	(5.81E-05)	(0.0032467)
Air temperature	-0.0001025***	-0.0001127***	7.07E-05	0.0060242**
	(0.0000283)	(0.000029)	(0.000066)	(0.0029054)
Precipitation	-2.27E-07***	5.19E-08	5.60E-07***	0.0000149*
	(7.32E-08)	(5.66E-08)	(1.35E-07)	(8.02E-06)
Distance to the eastern edge	5.93E-08***	2.81E-09	-4.32E-08***	2.54E-06***
	(2.89E-09)	(4.30E-09)	(8.20E-09)	(1.06E-06)
Distance to the western edge	5.09E-08***	6.22E-09	-6.87E-08***	8.63E-06***
	(2.88E-09)	(4.40E-09)	(9.07E-09)	(6.10E-07)
Distance to the northern edge	1.12E-07***	4.73E-09	1.26E-07***	0.0000192***
	(6.46E-09)	(5.11E-09)	(1.23E-08)	(1.77E-06)
Distance to the forest edge	-5.35E-08***	-3.11E-08***	-7.18E-08***	-6.27E-06***
	(2.91E-09)	(2.16E-09)	(4.33E-09)	(3.76E-07)
Distance to the buffer zone	8.91E-08***	-9.07E-09*	1.82E-07***	3.46E-06**
	(6.43E-09)	(4.79E-09)	(1.52E-08)	(1.65E-06)
Distance to the nearest road	-8.87E-08***	-3.00E-09	3.58E-08***	2.86E-06***
	(2.93E-09)	(2.68E-09)	(7.01E-09)	(2.75E-07)
Distance to the nearest archaeological site	7.93E-09***	1.17E-08***	-1.32E-08**	0.0000156***
	(2.26E-09)	(1.90E-09)	(6.25E-09)	(1.59E-06)
Elevation (m)	-4.61E-06***	-2.64E-07	-1.31E-06*	-0.0001931***
	(2.01E-07)	(1.65E-07)	(7.01E-07)	(0.0000245)
Biodiversity presence	-0.0000148***	-4.58E-06*	7.94E-06	-0.0002841
	(3.26E-06)	(2.63E-06)	(6.77E-06)	(0.0002145)
2000-level biomass	-0.0000163***	-2.02E-06***	-5.99E-06***	-0.0001574***
	(3.16E-07)	(2.68E-07)	(5.00E-07)	(7.66E-06)
Soil toxicity	0.0006621***	0.0001217***	0.000204***	-0.0044066***
	(0.0000201)	(0.0000276)	(4.23E-05)	(0.0008233)
Distance to the nearest city center	-1.21E-08***	-4.67E-09**	6.45E-09	1.88E-06***

	(2.48E-09)	(2.37E-09)	(4.72E-09)	(1.87E-07)
Distance to the nearest clearing	-2.79E-08***	5.24E-09**	-2.70E-08***	1.81E-06***
	(3.36E-09)	(2.52E-09)	(5.97E-09)	(3.84E-07)
Long-inhabited	0.000324***			
	(0.0000211)			
Industrial	-0.0002119***			
	(0.0000242)			
Constant	-0.0096558***	0.0030268*	-0.00546	-2.62205***
	(0.0017684)	(0.0017091)	(0.003905)	(0.2449847)
Observations	4,835,680	2,190,480	1,288,688	200,352

Note: Results represent annual effects of each variable on forest loss. Observations are 30m by 30m pixels. Standard errors clustered at the concession level and are in parenthesis. Unmatched pixels were dropped from the analysis.
*** p<0.01.
** p<0.05.
*p<0.10.