

Review Article

Thirty years of community forest management in the maya biosphere reserve: A review of its successes and challenges for conservation and governance of tropical forest socio-ecological systems

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ABSTRACT

Researchers and policymakers have promoted Community Forest Management (CFM) as an effective strategy for tropical forest conservation and the sustainable development of local communities. However, the literature suggests mixed results, with CFM performance below expectations globally. Besides, determining the long-term effectiveness of CFM is always a challenge in tropical landscapes. Therefore, this study conducts a bibliometric and content review of CFM implementation in the Maya Biosphere Reserve in Guatemala, a long-term pioneer model in the tropics. We analyzed its impact on forest conservation and the socioeconomic well-being of community concessionaires. Analyzing 181 scientific publications indexed in Scopus, we identified key research trends and predominant indicators in CFM evaluation. The results show that the model has significantly contributed to reducing deforestation and generating local economic benefits, yet it faces challenges related to governance, land tenure security, gender empowerment, and pressure from external actors. Despite its achievements, the literature suggests that CFM assessments have been fragmented, often prioritizing specific aspects without a comprehensive approach. Based on these findings, we propose the inclusion of new evaluation indicators and emphasize the need for interdisciplinary monitoring to enhance the model's socioecological sustainability.

Introduction

Deforestation and forest degradation are structural problems framed within economic, social, and political systems and interconnected with other global challenges. Multiple sectors (agricultural, forestry, urban) impact and simultaneously influence them, with the effects varying across different regions of the world (Curtis et al., 2018). In recent decades, both deforestation and forest degradation are specifically located in the tropics. The trends are alarming: 17% of tropical rainforests have disappeared since 1990, and 10% of the remaining forests in 2019 are degraded or disturbed, which may lead to the total disappearance of undisturbed tropical rainforest regions by 2050 (Vancutsem et al., 2021). The greatest threat to natural tropical forests and their vertical

structure is agricultural expansion, among other human disturbances such as selective logging and climatic disturbances such as fires (Bourgoin et al., 2024). These problems also relate to the expectations of tropical timber, linked to increasing demand (Ngo Bieng et al., 2022). Addressing deforestation and degradation requires coordinated actions across different levels of governance and economic sectors.

Even though researchers and policymakers have not found a definitive solution to reverse the declining trend, they have increasingly recognized that “the solution to the shortcomings of the conventional approach to forest protection is to place more trust in the resource management practices of people who have long lived in the forest and to adopt a rights-based approach” (Sunderlin et al., 2008). Indeed, conservation experts and initiatives, from which Indigenous Peoples and

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representatives, highlight globally the crucial role of IPLC in protecting nature and biodiversity. This is where co-management systems come into play, as they allow for local participation in resource governance and a more equitable distribution of benefits while maintaining the State as the controlling entity (Cronkleton et al., 2012). A highly promising practice that precedes modern civilization is community forest management (CFM). According to Gilmour (2016), CFM (Community Forest Management) is the set of initiatives, sciences, policies, institutions, and processes that promote local empowerment in government and decentralize the management of forest resources, considering customary and indigenous law and encompassing social, economic, and conservation dimensions. It works from small-scale reforestation schemes, community-business partnerships, small forest enterprises, and indigenous management of sacred sites of cultural significance.

The CFM, then, involves increasing the role of IPLC in the governance and management of forest resources through formalized customary and indigenous initiatives, as well as government-led initiatives. Ostrom developed this narrative in the 1990s, stating that when given adequate property rights over the forest commons in their area, local communities can self-organize and establish their institutions that regulate the use of natural resources, promoting sustainable management (Ostrom, 2015). Consistently and in the context of tropical developing countries, policy reforms in favor of common management (involving IPLC) emerged as a response to the struggles of rural and Indigenous populations against increasing rates of deforestation, encroachment on Indigenous lands, and social exclusion. The book “Forty Years of Community Forestry: A Review of its Extent and Effectiveness” (Gilmour, 2016) reports that in Latin America, West Africa, and Southeast Asia, around 60 million indigenous people live within tropical rainforests. In Latin America, traditional systems of autonomously initiated management predominate over huge areas, categorized as indigenous territories, extractive reserves, (agro) extractive and forestry settlements, and community forest concessions. This translates into 270 million hectares (or 32.3% of its forest lands) under any type of CFM regime (Gilmour, 2016). Community-based conservation strategies have great potential for conserving vast tropical areas and empowering numerous vulnerable, dependent populations, assuming viable enterprises linked to biodiversity generating local benefits (Salafsky et al., 2001).

While its diversity of regimes allows for various forms of forest management and dependent population involvement, determining the effectiveness of CFM is not easy. Related socioecological outcomes are generally safely expected (Teitelbaum, 2014).

A common approach is therefore to examine the relationship between community forestry and poverty alleviation, as well as other criteria and indicators (C&I) of participatory governance, local economic benefits, and multiple forest uses (Teitelbaum, 2014). The resulting outcomes highlight that tropical countries have not yet reached the optimal potential of community forest management. Its assessments are heterogeneous, and rankings are often below expectations (Gilmour, 2016; Salafsky et al., 2001). The failure is related to counter-intuitive strategies adopted by state actors related to co-management “bundles of rights”. We may cite, for example, the level of intervention that communities have in matters of access, withdrawal, management, exclusion, and alienation over the resource in question (Cronkleton et al., 2012). White and Martin (2008) reported for example that in 16 countries across Africa, Southeast Asia, and the Americas, governments more frequently granted state forest concessions to the industrial sector than to local or indigenous populations.

In this context characterized by mixed and suboptimal results, co-management systems, while potentially promising, are also intricate and delicate. Many challenges still exist, and progress has often been slow in determining to what extent the CFM is functional and where it can be improved (Sunderlin et al., 2008).

This work aims to contribute to improved knowledge of the challenges and opportunities associated with long term implementation of

the CFM in the Anthropocene tropical forest landscapes. We specifically focus on the CFM implemented in community concessions in the Maya Biosphere Reserve, part of the Selva Maya forest located in the northern territory of Guatemala. Guatemala is a vulnerable tropical country where natural ecosystems are subject to multiple pressures. Ecological pressures are seen in declined national forest area, canopy opening, and landscape fragmentation. This results in an average loss of 15,000 ha/year between 2000 and 2017 (FD-MSDRM et al., 2021).

The CFM implemented within community concessions located in the northern part of Guatemala resonates both nationally and internationally. As in numerous tropical forest landscapes, numerous socio-ecological and economic pressures threaten forest ecosystems within the Maya Biosphere Reserve. This ranges from wildfires and land use changes in and around the concessions for agricultural activities (Carías Vega, 2019) to livestock activities with 60–75% possibly linked to drug trafficking (Devine et al., 2020). However, compared with other threatened forest landscapes, thirty years implementation of CFM is related to forest maintenance in the North of Guatemala. Sufficient scientific literature allows for an analysis of the effectiveness of CFM implementation over time, listing the challenges that have been resolved and those pending development.

This paper, therefore, aims to provide a review of solid, up-to-date, and accessible knowledge on the real effectiveness (evaluation) of the long-term implementation of the CFM modality in the Maya reserve biosphere in Guatemala, a highly pressured tropical forest landscape. Besides a detailed bibliometric analysis of existing CFM evaluations of the selected community forest concessions, we first discuss the trends in scientific publications in relation to the historical context within the reserve. We therefore respond to the following main questions: (i) What are the leading indicators used in scientific works evaluating the CFM model implemented in the MBR? (ii) What are the main results of the evaluation? (iii) Which indicators do researchers overlook in existing analyses but find potentially interesting and worth including in future evaluations of the CFM model?

Our findings allow us to suggest important recommendations to update CFM evaluation and improve CFM implementation, which would maintain forests and people coexisting in heavily impacted tropical landscapes.

Materials and methods

Study Site

We studied the CFM implemented in community forest concessions within the Maya Biosphere Reserve, located in the department of Petén, northern Guatemala (Fig. 1). The reserve was established in 1990 as part of the Peace Accords after a civil war in the country, and in agreement with the State and other international actors. The aim was to empower local communities in land management. It was created in a place where local communities settled about 100 years ago for the small-scale extraction of chicle (*Manilkara zapota*) and mahogany (*Swietenia macrophylla*) (Devine, 2016; Radachowsky et al., 2012). Today, about 180,000 people inhabit the reserve (Gray et al., 2015). Covering approximately 2.1 million hectares, the reserve includes three different zones, each defined by its type of management (Fig. 2): (1) the Core Zone (767,000 ha, 35% of the reserve), consisting of two national parks and “biotopes” exclusively for conservation, scientific research, and tourism; (2) the Multiple Use Zone (848,400 ha, 40%), for low-impact natural resource management activities—where the community concessions studied in this paper are located—; and (3) the Buffer Zone (497,500 ha, 24%), which is a 15-kilometer strip along the southern boundary of the reserve, where other management activities (such as agriculture) are permitted (Hodgdon et al., 2015). Besides the multiple national pressures on land and natural resources, the forest concessions belong to a region with historical territorial disputes, and constant pressures from high scale projects of exclusive mass tourism. With almost 30 years of



Fig. 1. Location of the Maya Biosphere reserve in the North of Guatemala, department of Petén (Hodgdon et al., 2015).

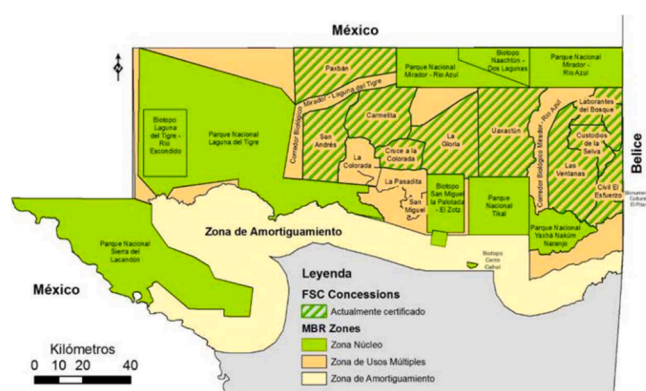


Fig. 2. Territorial division of the Maya Biosphere Reserve (Hodgdon et al., 2015).

implementation, this CFM is considered a pioneering Latin American reference for long-term CFM in the tropics, but its challenges and areas for improvement are also recognized (Rodríguez Solorzano & Fleischman, 2018).

A report by Rainforest Alliance (Rosales, 2010) highlights the importance of the Association of Forest Communities of Petén, which brings together 23 communities representing 30 local communities in the negotiation of greater community rights. It also highlights the relevant impact of the Community Forest Services Company on commercial and technical support to its member communities. The evolution of the reserve over the years reveals that environmental protection and democracy intertwine in complex and sometimes even contradictory ways (Sundberg, 2003). While there is a large grey literature on concessions, such as the technical documents on annual monitoring and evaluation of the concessions outside of traditional publishing and distribution channels, there is also relevant published scientific literature (Radachowsky et al., 2012). Community concessions are constantly evaluated, either by the Forest Stewardship Council to certify forest management activities and the commercialization of associated forest resources or by the State, since it continues to be the regent of the area (CONAP, 2019).

Systematic Review

This comprehensive review of scientific literature started with a pre-search discussion among the authors, which defined SCOPUS as the primary database. English and Spanish articles were targeted, as the topic has sparked research in both languages. All the available years in the publications were allowed, as the historical development of the research was also important to analyze. The search strategy, inclusion criteria, extraction of data and performance of its analyses encompass the PRISMA protocol 17-item checklist (Moher et al., 2015). Hence, we will present the methodology and the results following the logic of this adopted framework and protocol.

Literature compilation

We first performed several keyword searches in the titles, abstracts, and keywords of all the works indexed in Scopus until 2024. The different keywords were the following: evaluations, analysis, concessions, conservation, communities, forest, Maya biosphere reserve, Guatemala, and Petén. The previous eight words were combined, connected, and truncated in 8 different ways, thus resulting in various databases. Finally, the researchers chose the following combination because it presented the best number of results: (eval* OR analy*) AND ((concession* OR conserve* OR comun*) AND forest*) AND (guatemala* OR peten OR "mayan biosphere reserve").

Bibliometric analyses (Screening and Data Extraction)

We exported the database as a BibTeX document using the bibliometrix R package (<http://www.bibliometrix.org>). Indeed, its open-source environment, written in the R language, contains effective tools for high-quality numerical routines and integrated data visualization (Aria and Cuccurullo, 2017). Then, the researchers used a series of coding commands to obtain the following results: 1) annual scientific production, 2) countries of origin of the journal, 3) collaboration networks between countries, 4) thematic map, 5) h-index of the document, and 6) h-index of the author (of the dominant authors). Results 5) and 6) were important for the next step since each h-index ranked the documents in the database, thus organizing the database from the most cited documents to the least cited for content analysis in two different lists.

Bibliographic analyses (Data analysis)

The Scopus search yielded 180 papers, which the researchers subsequently filtered to 36 by organizing the documents by their h-index and author's h-index. These 36 documents were submitted for a comprehensive analysis, examining five key aspects of community forest management, as listed below. Identifying qualitative patterns allowed us to thoroughly understand the evaluations carried out on the CFM model in Petén. The team designed a matrix to organize the content of each article and its different perspectives based on the research on the CFM model, where each key aspect was subdivided into more specific criteria (Table 1). The specific criteria was coherent with the national evaluation process (CONAP, 2019) and internationally relevant for the thematics.

Results

Search Results

The following flow diagram helps as a visual guide of the following results, according to the methodological framework, showing the process of the extraction of 181 records and the final 36 used in the bibliographic analyses:

Table 2

Literature compilation

This publication aims to promote a comprehensive review of the achievements and challenges of the long-term implementation of the

Table 1
Summary of principles and criteria used in the Data Analysis.

Evaluation Principles	Criteria
Sustainable forest management	Damage to forests, soil, and water is reduced in timber and non-timber forestry activities The use and management of timber and non-timber forest resources is diversified The use of timber and non-timber forest resources is optimized The use of timber and non-timber forest resources is carried out according to their productive capacity There is a monitoring and evaluation mechanism that allows for improved forest management activities
Land use planning	Natural forest cover and use categories are maintained in accordance with the General Management Plans (PGM) or Annual Operating Plans (POA) The Management Unit has a management tool to counteract illegal activities Natural ecosystems are not affected by forest fires
Administrative/financial aspects	The concessionaire organization has functional administrative and financial structures The greatest possible economic benefits are obtained from the forest.
Social responsibility	Dealers improve their collective and individual economic and social conditions Employment opportunities for Dealers in the Management Unit have increased The organization contributes to strengthening the self-management of the dealers
Technical and legal regulations	The provisions of the Concession Contract, General Management Plans (PGM), Five-Year Plans, and Annual Operating Plans (POA) are complied with The productive activities carried out within the Management Unit have environmental instruments approved by the Ministry of the Environment The archaeological sites existing in the management unit are protected

CFM model in the Maya Biosphere Reserve in Guatemala. We synthesize the knowledge published on the model in relevant journals. This section presents the main findings of the references found in our literature review.

We identified 181 articles published across 129 journals worldwide using the selected keywords in the Scopus search. The most frequently represented journals were *Forest Ecology and Management* (7 articles), *Biodiversity and Conservation* (6 articles), and *Land Use Policy* (4 articles). Notably, the research process followed a spiral pattern: the bibliometric analysis highlighted articles relevant for content analysis, which raised new questions that warranted deeper investigation.

Bibliometric Analyses

The results of this first part correspond to the 181 articles extracted from the Scopus search. The first result from the Scopus data repository is the annual scientific production of the 181 publications retrieved (Fig. 3). The oldest publications date back to 1992, which makes sense since the authorities created the reserve in 1990. There were no significant increases in publications until 2004 - 2005, which makes sense since the area gained international interest from the beginning of the Mirador Basin conflict. This conflict, discussed latter, is the trigger for international research into the area, also explaining in some way the other peaks in 2011 – 2012 and 2020 – 2021. The boom in publications in 2016 – 2017 may also be related to that, but also to the fact that, for the first concessions, their 25-year contract was about to end, which may have raised the question of its effectiveness and renewal, and therefore the increase in studies.

The next step was to catalog the authors' countries and the type of collaborations (single or multiple) (Fig. 4). More than half of the database has been published by authors from the United States of America or Mexico, either as individual or collaborative publications, followed by

Guatemala (the country where the concessions come from). This makes sense since the first two countries are related to forest concessions, either indirectly or directly (the Yucatan Peninsula in Mexico, located in the same region as the Maya biosphere reserve received migrants during the Guatemalan civil war and the migrants were in touch with locally community-based initiatives, USAID's involvement in the development of the concessions). Speaking of continents, most of the publications come from the Americas (10 countries, either as individual or collaborative publications). On the other hand, publications from Europe (7 countries) and Asia/Oceania (2 countries) contributed mostly to collaborative publications.

Fig. 5 now visualizes countries as collaboration networks, digging deeper into the origins of scientific publications. The darker the shade of blue means that it is a country with a higher number of publications, something already discussed in Fig. 4. In this case, it is important to highlight the collaborations between countries, shown by the orange lines connecting them. Most of the lines end in the top three publishing countries: the USA, Mexico, and Guatemala, which are also the countries with the darkest shade of blue. It is also worth mentioning that China and some countries in Oceania/South America are painted in blue even though there are no publications recorded there, but that is only because authors from these countries are part of a working cluster with authors from Mesoamerica, the orange lines will always point to the actual countries where the collaboration comes from.

In this paper, Multiple Correspondence Analysis, a multivariate statistical technique used to analyze associations between categorical variables, explaining the current research landscape and key areas for future research through keywords retrieved from the Scopus database (Fig. 6). The co-occurrence of keywords results in a series of clusters, and their position along the scatter diagram represents their thematic relationships and the strength of the association. The clusters located in driving and basic themes (blue and red, respectively) are the largest, meaning they are well-developed throughout the scientific publications. The blue cluster is related to the main objective of the concessions, which is to ensure the conservation of the forest ecosystems of the Maya Biosphere Reserve. The red cluster refers to the geographical location of the studies, as to one of the main problems of the area: deforestation. On the other hand, the purple cluster is in a niche topic, and the green cluster is the closest to the center, so they could be considered the most influential (conservation of fauna/flora species) or the most standard (social topics). The emerging/declining topics are consequently less dense due to the low number of publications. There are, for example, publications related to the Quetzal bird (*Pharomachrus mocinno*), an emblematic bird of the Mayan civilization and the Republic of Guatemala.

Bibliographic Analyses

Although the document's h-index and the author's h-index yielded 90 statistically relevant articles, a total of 36 articles were relevant for the content analysis. This occurs because some researchers mention the Maya Biosphere Reserve without specifically referring to the CFM model, or they do not mention it in enough depth to allow an exhaustive analysis of the model itself. Initially, the 90 abstracts were used as the main criterion for the content analysis, but for some cases, it was necessary to delve deeper into the methodology/results section. Table 3 summarizes the final 36 articles indexed in the matrix discussed in Materials and Methods and whether they come from the H-index of the documents or the authors. It is worth mentioning that there were seven duplicate articles, meaning that both bibliometric analyses categorized them as relevant, and therefore, they were the first to be indexed.

Figs. 5 and 7 shows the main themes of the scientific publications, which arise from identifying the central idea of each work and categorizing them into 13 different groups that evolved during the content analysis. Local governance and biodiversity (flora and fauna) emerge as the most frequent research topics (with 19% and 17%, respectively),

Table 2
Summary of database search results and filtering using a PRISMA flow diagram for systematic review.

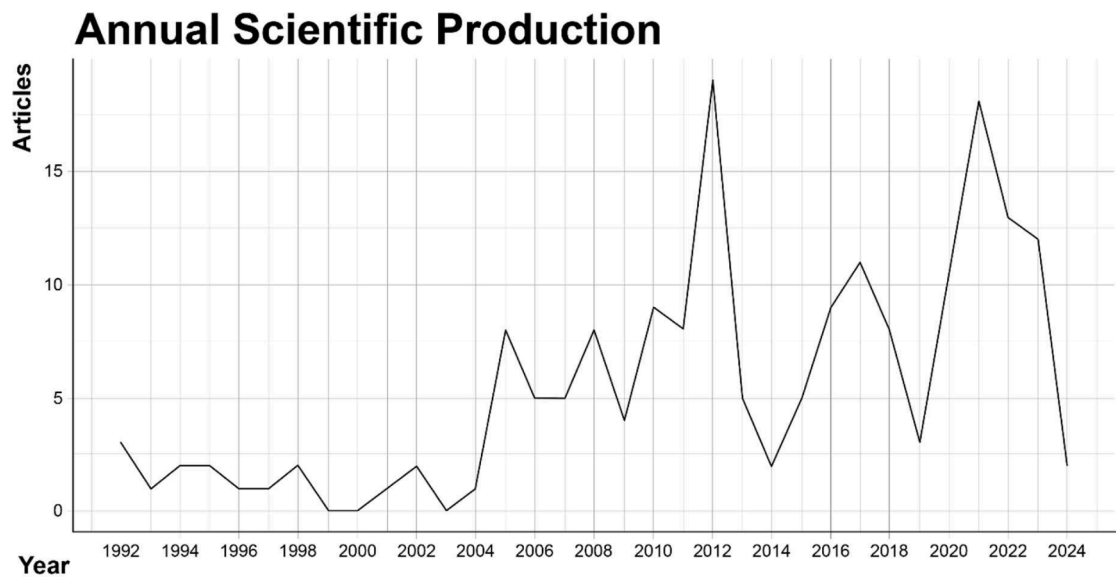
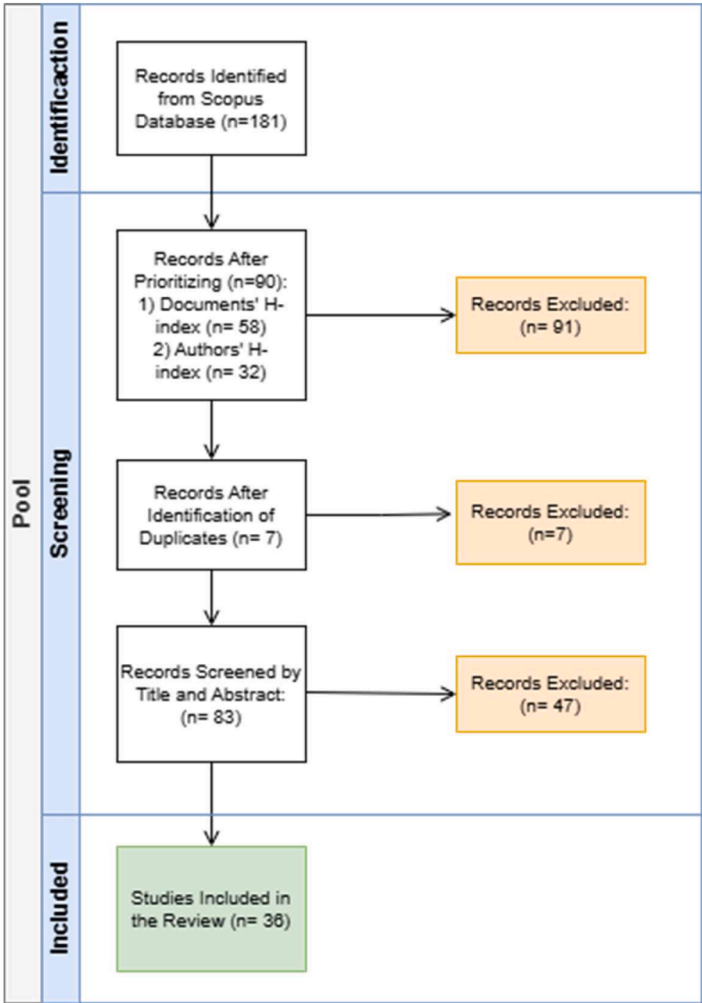


Fig. 3. Annual scientific production of scientific publications taken into account in our analysis.

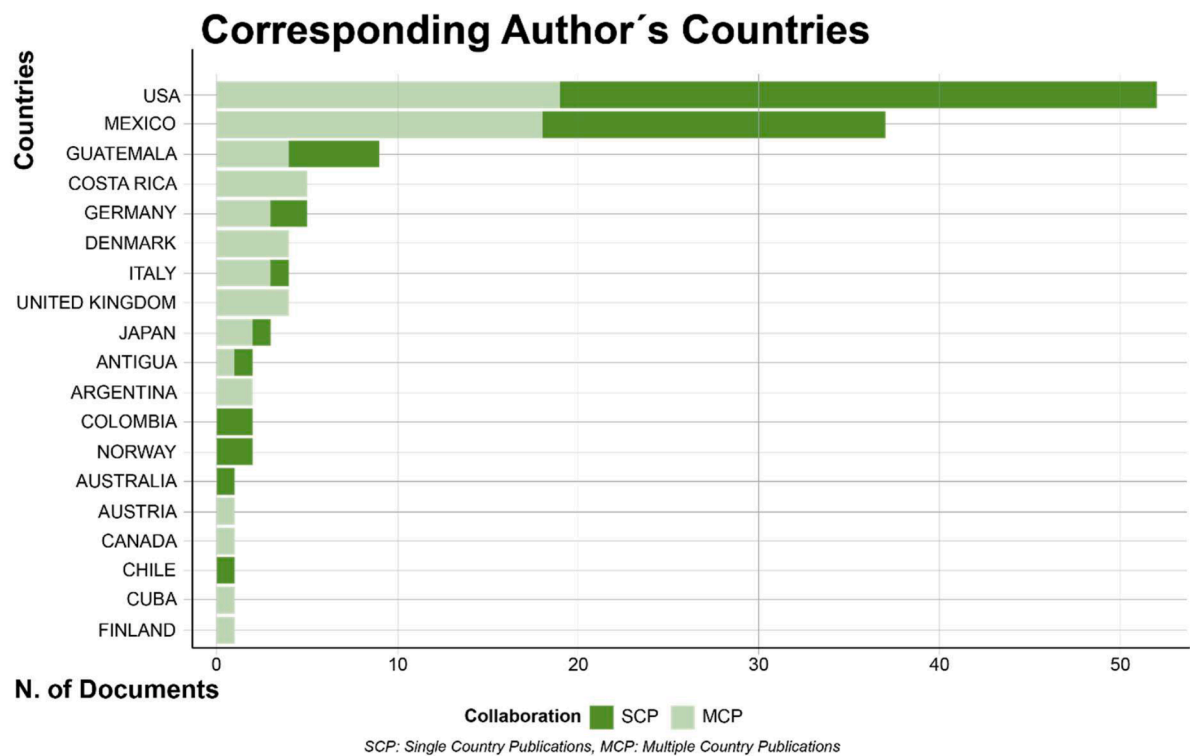


Fig. 4. Countries of the authors corresponding to the scientific publications, with colors according to individual publications (light blue) or collective publications (orange).

Table 3
Summary of scientific publications used for content analysis.

Category	References
Documents' H index	Blackman, 2015; Carias Vega & Keenan, 2016; Carr, 2008; Colchero et al., 2011; Hayes et al., 2002; Manuel-Navarrete et al., 2006; Millner et al., 2020; Mutchnick & McCarthy, 1997; Nesheim & Økland, 2007; Rodriguez Solorzano & Fleischman, 2018; Salafsky et al., 1993; Sesnie et al., 2017; Sundberg, 1998; Taylor & Cheng, 2012; Thornton et al., 2011; Tobler et al., 2018; Wright et al., 2007; Ybarra, 2016
Authors' H-index (of dominant authors)	Baur et al., 2012; Bocci et al., 2020, 2022; Bocci & Mishra, 2021; Butler, 2021; Butler & Current, 2021; Devine, 2016; Devine et al., 2021; Jamkar et al., 2023; Taylor et al., 2013; Tellman et al., 2021
Duplicates	Bocci et al., 2018; Bray et al., 2008; Devine, 2018; Devine et al., 2020; Fortmann et al., 2017; Monterroso & Barry, 2012; Radachowsky et al., 2012

which aligns with the fact that forest concessions in Guatemala aim to ensure the conservation of natural resources and ecosystem services in the Maya Biosphere Reserve through partnerships with IPLC inhabitants. Narco-degradation, Deforestation, and Administration as EFC (Community Forest Enterprise) are tied with 11%. These topics are also relevant to the reserve since the first is a multi-structural problem commonly observed in the tropics, and the other two represent the challenges that community concessions have been resolving over time.

Our methodology proposes that each scientific publication, based on their research, poses a series of arguments that either support or question aspects of the CFM model. This resulted in the accumulation of quantitative ratings (which could be positive or negative integers), ending in a final rating towards the forest concessions in Guatemala. Fig. 8 summarizes this information as a histogram to illustrate how the ratings distribute across the 36 articles reviewed. With the rating interval with the largest number of articles (13) being (-6, -1] and fewer articles at the extreme rating intervals [-11, -6] and (14, 19], the

distributions can be considered somewhat skewed to the left. However, there is a secondary peak at the intervals (-1, 4] and (4, 9], each with eight articles, amounting to 16 articles with a positive outlook, followed by four more articles in the interval (9,14]. This suggests a bimodal distribution, indicating two distinct groups or clusters of ratings. While most articles have ratings in the interval (-6, -1] (suggesting a not-so-strong negative opinion due to its low number of negative arguments), the secondary concentration has higher intervals along (-1, 4], (4, 9] and (9,14], indicating that positive opinions have more supporting arguments.

In the next step, we categorized 11 general recommendations that evolved throughout the content analysis based on the general idea of the recommendations in each article. The most popular recommendation revolved around increased in scientific research, as 17% of the articles urged it to be a key component for local decision-making processes. Next, with 14%, it was also frequently mentioned that the reserve had an interesting diversity in how communities manage their concessions, which was important to monitor. Finally, both the study of economic insertion in the CFM and the strengthening of governance were the main recommendations for 11% of the scientific publications (see Fig. 9).

In the final stage, we related the results of our literature review to the CONAP M&E system, as presented above, to provide inputs with local and national relevance. In this direction, it is possible to link the research topics of the publications with the five different guiding principles of the M&E system (sustainable forest management, territorial management, administrative/financial aspects, social responsibility, and technical/legal regulations). From there, we see that most articles deal with issues of forest management, social responsibility, and technical or legal aspects (see Fig. 10). The following graph summarizes the importance of each principle of the M&E system within the analyzed research and, therefore, the criteria with the highest presence within the publications - which are not necessarily exclusive of the other principles. In the first principle, the discussion of the use of wood and non-wood resources is present in 12 articles, as well as its diversification and optimization. Within social responsibility, the discussion revolved

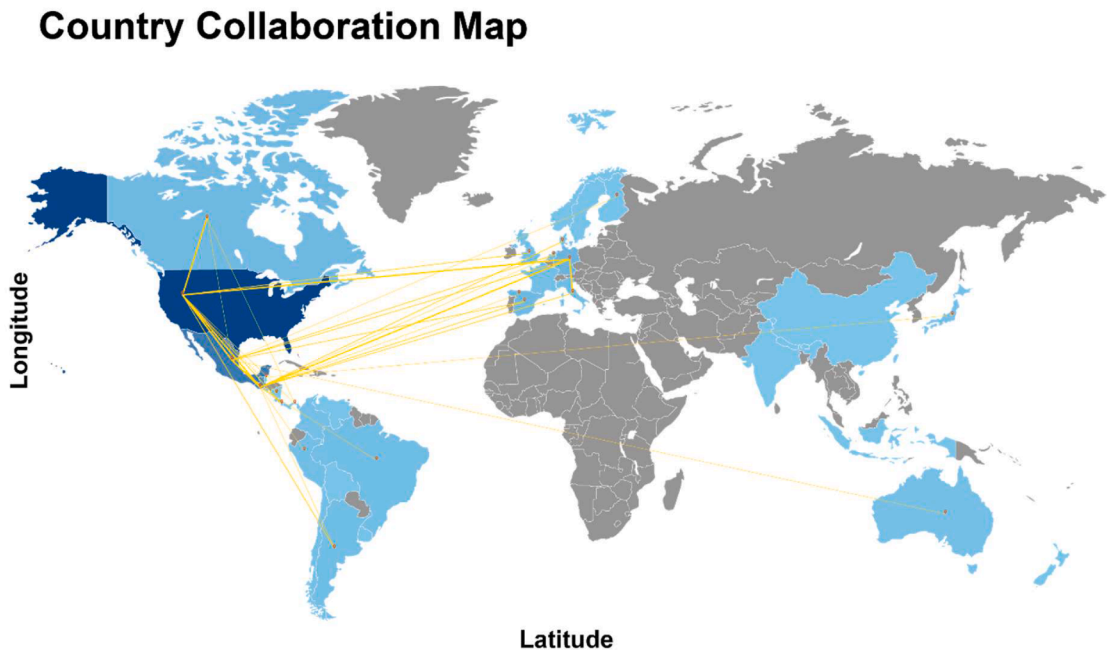


Fig. 5. Map of collaboration between countries for scientific publications, with orange lines indicating the cooperation between them and the intensity of blue hue indicating the frequency of publications.

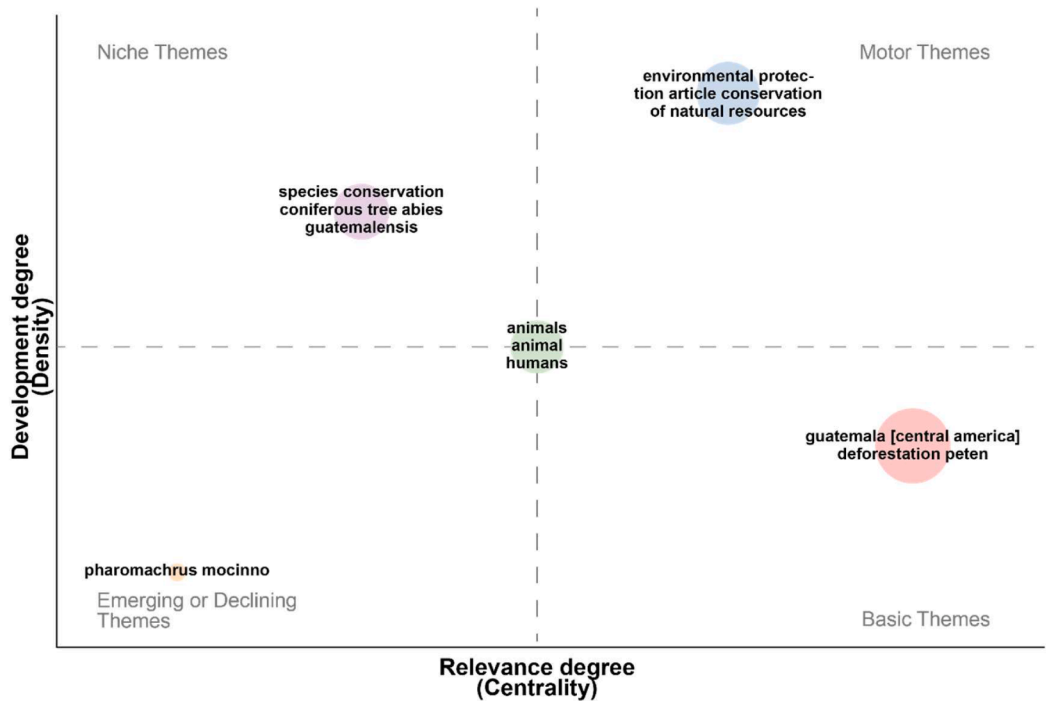


Fig. 6. Multiple Correspondence Analysis keyword analysis for scientific publications, with four categories within the Cartesian plane and 5 clusters of topics.

around 18 articles on strengthening community self-management and increasing employment opportunities and local economies. Territorial management was also relevant in the discussions, as 13 articles mention the importance of maintaining forest cover in the area thanks to the presence of forest concessions. This analysis shows the relevance of each of the criteria of the CONAP M&E system within the global scientific community.

Discussion

This paper provides for the first time a systematic review and bibliometric analyses of achievements and challenges related to long-term implementation of forest management within community forest concessions. Bibliometric analyses have the potential to perform transparent reviews by identifying the knowledge base, conceptual structure, and social network of a particular scientific community (Aria & Cucurullo, 2017). The sampling provided by the H index of documents and authors, which measured the contribution of these factors through their

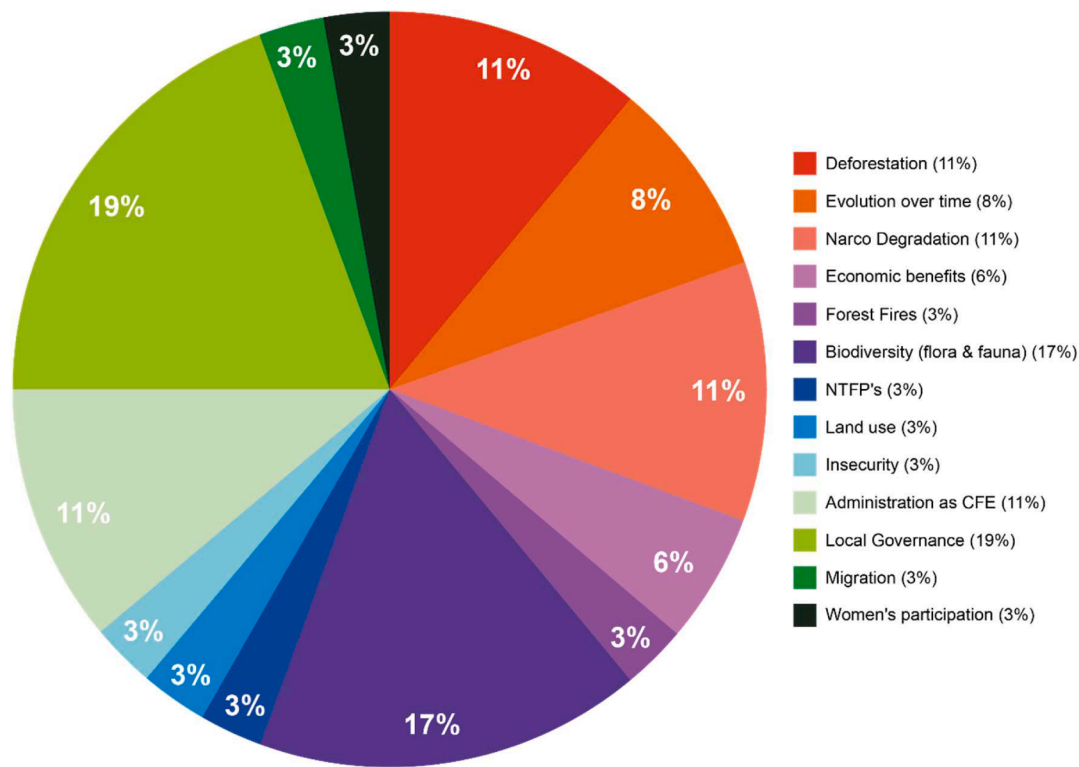


Fig. 7. Main topic analyzed, with arrows highlighting the top 5.

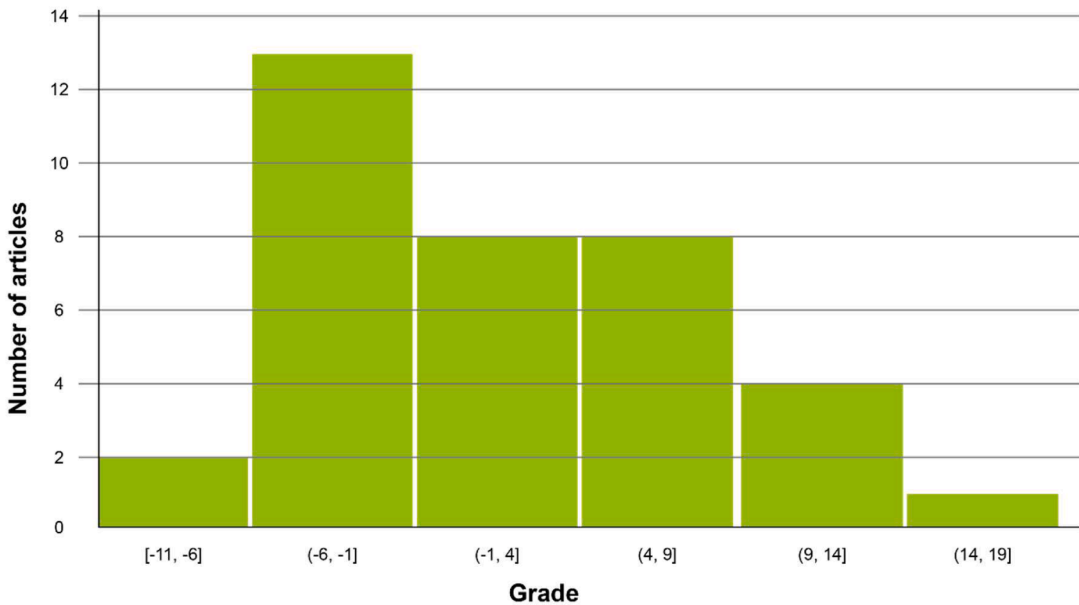


Fig. 8. Distribution of ratings of scientific publications on the evaluation of the CFM model in Petén, Guatemala.

productivity and impact on a specific database, resulted in relevant information for the Content Analysis. This analysis identified knowledge gaps and limitations, as well as a response to the challenges of the present CFM implementation in a local context and the evaluations applied to it. The results allow us to perceive the diversity of disciplines, interests, actors, and levels involved in the conservation of tropical forest territories in interaction with the involvement of IPLC. This review also allows us to identify how scientific involvement has contributed to the historical visibility of the area.

Trends in scientific publications and historical context within the Maya Biosphere Reserve

Scientific publication trends and specifically the research peaks (Fig. 3) coincide almost perfectly with the historical context of the Maya Biosphere Reserve. The first peak in 2004 corresponds to a proposal called “El Mirador Basin”. Around 2000, a scientific team defined the Mirador Basin as a geographic entity, gradually gaining support from national and international groups (J. A. Devine, 2018). However, local actors in the reserve questioned this designation, arguing it belongs to

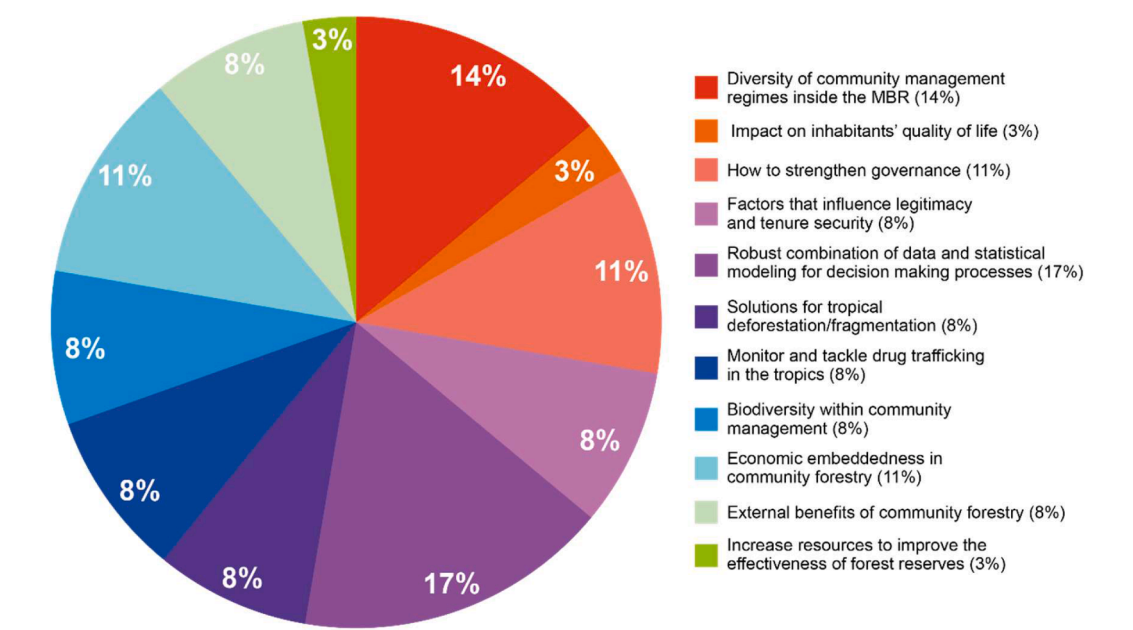


Fig. 9. Main recommendations, with arrows highlighting the top 4.

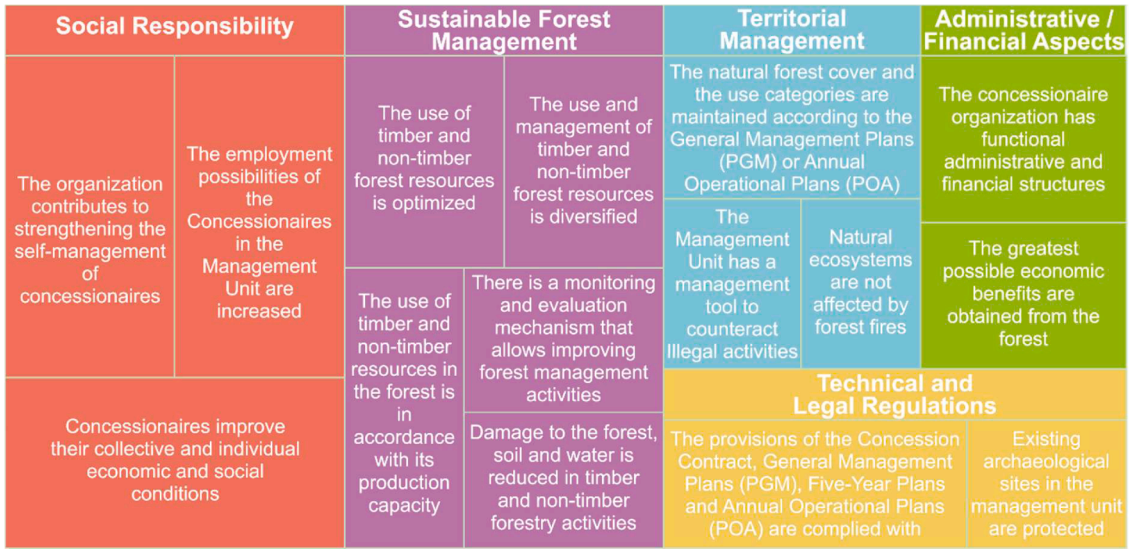


Fig. 10. Treemap of the principles and criteria of the analyzed in the consulted publications, with colors representing each of the principles and boxes framing the popularity of each criterion within the publications.

the San Pedro River basin that flows into the Usumacinta River (J. A. Devine, 2018). Besides, the “El Mirador Basin” proposal planned to turn the Maya Biosphere Reserve into a major archaeological and ecotourism site. The proposal required taking land from at least five community concessions and affecting local livelihoods based on sustainable exploitation of forest resources, from which timber extraction, which accounts for up to 65% of local incomes (Escobar, 2020). In 2002, the proposal was almost institutionally an legally approved. However, authorities rejected the “Mirador Basin archaeological zone” proposal in 2005 after two national commissions reviewed the issue and recommended its rejection, aligning with initiatives led by IPLC. (J. A. Devine, 2018).

From 2008 to 2010, the publication peaks corresponded to the conflict resurfacing after 2008 with the launch of the Four Balam (Four Jaguars) ecotourism project led by the government. In 2010, lobbying efforts pushed again towards the implementation of The ‘Mirador Basin

archeological zone” (J. Devine, 2014). The association of local communities and actors promoting archeological mass tourism met to discuss “their contrasting visions, territorial claims, and competing histories of the forests of northern Petén” (J. A. Devine, 2018): the initiative faded.

More recently, the publication peaks ranging from 2016-2024 corresponded to a reignition of the debate, again through a proposal supporting the implementation of the renamed Mirador-Calakmul Basin (Escobar, 2020). Like earlier plans, it threatened to reduce community forest concession areas for a private mass tourism park, increasing IPLC vulnerability. The proposal stalled, again coherently with the actions of forest community actors, national and regional supports within the Maya Biosphere reserve (Devine, 2018). Nowadays, a “grey zone” remains due to ongoing political and economic pressures (Butler, 2021). Nonetheless, local empowerment is growing, primarily through the local association of forest communities and Community Forest Services

Company. These institutions have strengthened IPLC's identity and economic development (Blackman, 2015).

Although the origins of these scientific publications may be diverse, it is a fact that the historical context and controversies have attracted the interest of the international scientific community in one way or another. This resulted in a series of transdisciplinary socioecological studies within the reserve and, more specifically, within community forest concessions. Discussing the most relevant conflict of interest within the reserve is important. The conflict is directly reflected in the results line graph and its peaks of relevant publications, but also indirectly in other parts of the results, such as the topics studied and the recommendations in the research. The content analysis we made provided elements to answer the questions we presented in the introduction of the paper.

(i) What are the leading indicators used in the studied scientific works evaluating the CFM model implemented in the Maya Biosphere Reserve?

According to our content analysis, the most significant incidence within the publications, were Sustainable Forest Management and Social Responsibility. Within these two, there was a special interest in indicators of optimization and diversification of timber and non-timber resources and the general improvement of the quality of life of the concessionaires. All these concepts have a common starting point: the generation of income for IPLC from their local environment (Fortmann et al., 2017; Bocci et al., 2018). These socioecological indicators have broader policy implications, especially considering that a significant portion of tropical deforestation occurs on the agricultural frontier (Vancutsem et al., 2021), where people view agriculture as a unique productive landscape alternative. Many articles conclude in their results that deforestation (land use change) would have been significantly higher in the absence of forest concessions (Salafsky et al., 1993; Millner et al., 2020; Bocci et al., 2022), and others conclude that these practices allow for the comprehensive development of the territory (Butler & Current, 2021; Baur et al., 2012), as it is related to a sustainable locally significant alternative.

However, the long-term viability of these concessions is taking place in a complicated socio-political context. Many publications considered government intervention within the CFM and worried about inefficient government oversight and law enforcement, as well as a lack of timely and politically acceptable sanctions (Devine et al., 2021; Rodriguez Solorzano & Fleischman, 2018; Radachowsky et al., 2012). On the other hand, the influence of external actors has driven the term “narco degradation” which implies how drug trafficking can erode livelihoods in a specific context (i.e., livestock or forest fires) (Devine et al., 2021; Tellman et al., 2021; Wright et al., 2007). Like deforestation, narco-degradation has become more evident in national parks more so than in community concessions, thanks to local governance and local forest identity (Devine et al., 2020; Monterroso & Barry, 2012).

(i) What are the main results of the evaluation?

Most scientific publications consider that the greatest impact of the CFM model within the reserve is the preservation of forest cover, whether the concessions are long- or recently inhabited or uninhabited (Bray et al., 2008; Fortmann et al., 2017). Also, according to Fortmann et al. (2017), across different concession types, long-inhabited areas showed the highest rate of avoided deforestation (8,548 ha), followed by nonresident (8,348 ha) and recently settled concessions (4,955 ha), despite variations in the total forest area. Some publications show that concessions have achieved better maintenance of forest cover than their neighboring national parks—parks that displaced local communities—and, in some cases, even halting deforestation by 73% (Blackman, 2015; Bray et al., 2008). In addition to forest cover, studies have focused on the impact of forest concessions on local faunal diversity. Some studies recommend not overly fragmenting the landscape so that widely

distributed animals do not suffer frequent exposure (Thornton et al., 2011), and others consider that the cleared areas within the concessions do not significantly affect the level of occupancy or population density of jaguars and other small mammals (Tobler et al., 2018). The long history of forest exploitation in Petén has had a significant positive change with the implementation of concessions and biological corridors in the Maya Biosphere Reserve, together with the current monitoring of species and sustainable forest management practices (Butler, 2021; Carias Vega & Keenan, 2016; Mutchnick & McCarthy, 1997). Within the community concessions, more than 80 species of trees are useful, either for commercial or local use (Mutchnick & McCarthy, 1997), allowing for a diversity of income for the inhabitants. Bocci et al. (2018) concluded that concessions have a significant impact on annual income in both resident and nonresident communities, increasing their annual income by \$1000 and \$2335 respectively. Then, they conducted a choice experiment that revealed that households within the reserve consider NTFPs (non-timber forest products) and tourism as extremely valuable activities (Bocci et al., 2020). NTFPs have become an added value to timber harvesting, not only by providing stable income throughout the year (by rotating products) but also by not exceeding exploitation limits (Baur et al., 2012; Bocci et al., 2018; Salafsky et al., 1993) and by including a diversity of local actors (women, young people). Butler (2021) made what could be considered the most comprehensive analysis of community concessions as CFEs (community forest enterprises), stating that combining the commercialization of timber species such as mahogany (*Swietenia macrophylla*), Guatemalan cherry (*Lonchocarpus castilloi*), Santa Maria (*Calophyllum Brasiliense*), Spanish cedar (*Cedrela Odorata*) and tropical walnut (*Bucida buceras*) with NTFPs shows a clear improvement in capital over time. Probably the most important NTFP are the Xate leaves produced by three species of the genus *Chamaedorea*, which are harvested all year long and exported to the US and Europe (Radachowsky et al., 2012). Despite ongoing conflicts among stakeholders, the community forest concession model in Petén is broadly regarded—by nearly all consulted experts—as an effective strategy for forest conservation (Manuel-Navarrete et al., 2006).

(i) Which indicators do researchers overlook in existing analyses but find potentially interesting and worth including in future evaluations of the CFM model?

The creation of the Maya Biosphere Reserve changed regional power structures from the outset, empowering new actors to enforce a “dead” legal framework to address illegal activities involving logging, wildlife, archaeological sites, cattle ranching, and most importantly, drugs (Sundberg, 1998). Landing in such a complex context has not been easy for the CFM model, and while there are many achievements, there is also room for improvement. Increasing women's participation remains a challenge, but NTFPs are paving the way for this and would be worth monitoring more closely (Bocci & Mishra, 2021). Technical challenges from local inhabitants have also been overcome, with the initial inclusion of NGOs and research centers as guarantors of the CFM model. However, that relationship has now evolved to collaborate towards the constant monitoring of the evolution of the CFM model (Radachowsky et al., 2012) and the role of their community enterprises as a form of organization (Carias Vega & Keenan, 2016). Another relevant issue is the strengthening of the legitimacy and security of land tenure (Monterroso & Barry, 2012), which is negatively influenced by the lack of resources from the State and some technical aspects, such as the duration of concession contracts, buffer zone management and some commercial laws (Butler, 2021; Carr, 2008).

We propose in Table 4 some new indicators that could complement and innovate in the evaluation of forest concessions, as they are aspects not frequently evaluated but have the potential to generate relevant information. This aspect is very important, as there is a local, regional and international need to improve monitoring of such socioecological systems. In this direction, the indicators found in the literature can

Table 4
Summary of principles and proposed new criteria.

Principle	New Indicator	Reference from the literature
Sustainable Forest Management	Safe impact on local biodiversity	(Thornton et al., 2011) (Radachowsky et al., 2012) (Nesheim & Økland, 2007) (Mutchnick & McCarthy, 1997)
	Safe hunting activities	(Radachowsky et al., 2012) (Colchero et al., 2011) (Tobler et al., 2018) (Baur et al., 2012)
Social Responsibility	Influence on migration (internal and external)	(Radachowsky et al., 2012) (Bocci et al., 2022) (Taylor et al., 2013)
	Diversity in Leadership and Management	(Millner et al., 2020) (Bocci & Mishra, 2021) (Butler & Current, 2021)
Technical and Legal Aspects	Government influence	(Bocci et al., 2020) (Bocci et al., 2020) (Devine et al., 2021) (Devine, 2016) (Monterroso & Barry, 2012) (Devine, 2018)
	Influence from external actors	(Devine et al., 2020) (Sundberg, 1998) (Millner et al., 2020) (Butler, 2021) (Devine et al., 2021) (Taylor et al., 2013)

complement local monitoring efforts.

Conclusions and perspectives

In this paper, we attempt to answer the following central question: what have we achieved regarding the socio-ecological conservation of forests within the Maya Biosphere Reserve, thanks to the CFM model? Through a review of scientific literature, we provide a global evaluation of the CFM model, through exhaustive bibliometric and content analyses. We found that, although the CFM has demonstrated positive impacts on forest cover conservation and the socioeconomic development of local communities, its evaluation has often focused on isolated indicators (biological, social, or economic) without considering a holistic analysis of its socio economic and ecological effectiveness.

Globalization has made literature reviews crucial to synthesize past research and effectively use the existing knowledge base to provide evidence-based information and support professional judgment (Aria and Cuccurullo, 2017). The first part of this work draws on data from a Scopus query search, which helps synthesize and clarify the scientific community’s studies for the case study. Gathering information from the Scopus database involves the use of journal or author metrics and the collaborative networks of researchers, which is key to understanding the scientific and technical implications of a specific topic and therefore increasing knowledge (Montoya et al., 2018), which is the ambition of our on-going research.

Specifically for the topic studied, investing in monitoring and evaluating on community forests is important to record their benefits and improvements in both environmental and social aspects (Gray et al., 2015). In this work, the main knowledge promoted is that community concessions have played a crucial role in protecting ecosystems, avoiding deforestation rates comparable to those of stricter conservation areas. Likewise, the model has allowed the diversification of local

income through the sustainable use of timber and non-timber forest products. However, challenges remain, particularly concerning governance, land tenure security, and the influence of external actors, such as drug trafficking and commercial interests in the Mirador Basin.

In terms of future perspectives, it is essential to strengthen the monitoring and evaluation mechanisms of the CFM to ensure its long-term viability. It is recommended that the analysis of underrepresented indicators, such as diversity in leadership, government influence, and the effects of migration on community dynamics, be expanded. Likewise, the analysis highlights the need to improve coordination between local, national, and international actors to consolidate a sustainable and equitable forest management model. For future work on the topic, it would be important to include in the analysis the grey literature worked on in the CFM of forest concessions in Guatemala (i.e. State evaluations, local and regional technical reports...), as well as direct interviews with local actors, verifying what has been evaluated from the local and current perspective. Subsequently, different CFMs in Latin America could be compared, such as in Mexico or in Brazil, which also have diverse experiences in the CFM modality.

Finally, this work contributes to the discussion on the role of IPLC governance in the conservation of tropical forests, highlighting the importance of participatory and locally based approaches to face dramatic challenges of the Anthropocene. The continuity of research in this field will not only improve the effectiveness of the CFM in Guatemala but also provide valuable lessons for many other tropical contexts in which conservation and IPLC development go hand in hand.

CRediT authorship contribution statement

Silvia Ximena Ureta Cifuentes: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Fabián Marcelo Zamora Mejía:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Pedro Arnulfo Pineda Cotzoyaj:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Funding acquisition, Conceptualization. **Marie Ange Ngo Bieng:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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