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Article

Endurance and Adaptation of Community Forest Management in Quintana Roo, Mexico

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Abstract: Despite regional deforestation threats, the state of Quintana Roo has maintained over 80% of its territory in forests. Community forest management (CFM) has played a pivotal role in forest cover and biodiversity conservation in the region. In this article, we present the institutional, socioeconomic and environmental conditions under which community-based forest management has been consolidated in the tropical state of Quintana Roo, which occupies the eastern half of Mexico's Yucatan Peninsula. With a focus on management for timber and other market-based development strategies, we then examine the institutional and socioeconomic factors, as well as biophysical shocks, that have constrained community forestry development in the past 25 years, challenging its persistence. Following, we discuss how forest communities and institutions have responded and adapted to changing forest policies and markets as well as major environmental shocks from hurricanes and fires. CFM in Quintana Roo has shown resiliency since its institutionalization 30 years ago. Future challenges and opportunities include biodiversity conservation, carbon management through Reducing Emissions from Deforestation and Forest Degradation

(REDD+) initiatives, market strengthening, business management training as well as the implementation of alternative silvicultural systems, particularly to manage sustainable populations of commercial timber species.

Keywords: community forestry; ejido; forest cover; adaptation; Maya Forest; Yucatán

1. Introduction

Community forest management (CFM) recognizes that rural people living in and near forests have cultural and socioeconomic ties to these forests, and implies that: (1) local communities have some degree of responsibility and authority for forest management formally vested by the government, (2) some social and/or economic benefits are accrued locally, and (3) communities take some responsibility for forest health and ecologically sustainable forest use and management [1]. CFM first took hold in sustainable rural development strategies in the late 1970s, with international development and research institutions emphasizing its importance in meeting local needs, in deterring forest conversion to other land uses, and in supporting environmental protection [2]. Today, more than 30 years later, 11% of the world's forests and almost 1/3 of forestland in developing countries are recognized by governments as community owned or managed [3,4]. Substantial reports that CFM improves local incomes and livelihoods have been forthcoming [4–6], and there is growing evidence that forest cover in the tropics can be maintained by such local communities [7].

Mexico is recognized as a leading global example of CFM [8], with over half of its forests (55%) under communal ownership [9]—a distinguishing feature of CFM in Mexico along with a management orientation toward timber production [10]. Community forestry throughout the country has been accepted as playing a central role in forest conservation and rural livelihood improvement [11–13]. Founded upon decades of agrarian reform that institutionalized common-property rights and local governance structures, community managed forest landscapes in Mexico tend to show reduced or minimal deforestation compared to forest landscapes under other land uses [14], including conservation [15]. In the state of Quintana Roo, notable improvements in forest community livelihoods [11,16,17] and maintenance of forest cover [18–22] have been documented and attributed to successful management of forests by communities [23]. These "successes", however, have been based on a few selected cases, with limited state-wide analysis.

The case of Quintana Roo meets diverse conditions identified for successful CFM development: (1) secure tenure and rights to forest resources [4,24,25], (2) sufficient size and resources as well as clear boundaries of forest land [26], (3) decentralization of state forestry development and governance institutions [5,25–28], (4) generation of local income and accrual of economic benefits [4,5,25,26], and (5) influence and support of external international and local institutions [5,25]. Notwithstanding, since its formalization in the 1980s, CFM in Quintana Roo has endured changing forest policies, shifting economies and markets, as well as environmental shocks from hurricanes and fires. Bray [23] borrows from the adaptive management concept to explain how local forestry institutions and communities in Quintana Roo have persisted and evolved despite very complex, variable, and at times turbulent social and biophysical environments. These local institutions and communities are described as integrating

traditional knowledge with technical and scientific knowledge on forest resources and management, enabling a learning process through which changes in management practices and forest governance can promote adaptation [23,29]. Inevitable shifts and changes in policy and socioeconomic environments can both constrain and foment CFM development, as well as enhance the resiliency and adaptive capacity of local forest communities [23,29–31].

In this paper, we discuss historical, institutional, socioeconomic and biophysical factors that helped establish and consolidate community-based forestry in the state of Quintana Roo in southeast Mexico, highlighting management for timber and other market-based development strategies. We then analyze the 30-year period following clear designation of timber rights to local communities, focusing on institutional and socioeconomic constraints in addition to the biophysical shocks endured, describing how forest communities and institutions have responded and adapted to these constraints and shocks. Following, future challenges and opportunities for CFM in Quintana Roo are presented, and conclusions are offered with respect to integrating CFM into larger development and conservation goals. We draw on a variety of sources, such as bibliographic resources and the experiences of the authors working in the region. The Quintana Roo case study is particularly relevant in that it encapsulates dynamic human–forest relationships that have evolved and endured for more than 3000 years, demonstrating the adaptive capacity of both people and forests to changing policies, economic conditions and environmental factors. Few cases globally have been documented with such breadth of substantiated data over such a long period of time; examples of "successful" cases of CFM pertain to Central America, México and Peru [4–6]. Lessons learned indicate how community forest management can contribute to the overall goal of forest-based sustainable development and biodiversity conservation in the tropics.

2. Consolidation of CFM in Quintana Roo

Our analysis of CFM in Quintana Roo begins with an exploration of the historical contextual and biophysical conditions that have led to the prominence of community forestry in the region. We then discuss the institutional arrangements and local socioeconomic factors, which were conducive to CFM consolidation in the region.

2.1. History of Forest Resource Use

Forest products and ecosystems have played an important historical role in the region that is now the state of Quintana Roo. The use of these forests dates back as far as 2000 BC with the establishment of the Mayas in the Yucatan Peninsula [32]. Forests were cleared to construct architecturally magnificent and densely populated cities and to cultivate food crops and trees to support them. Shifting slash-and-burn agriculture was the norm and maize the primary crop in a very diverse production system [33] known as *milpa*. Today's forest reflects approximately 3000 years of Maya agroforestry, resource extraction, fire, drought, and hurricanes [34,35]. These human–forest interactions likely played a key role in current species composition and diversity [34]. Both anthropogenic and natural disturbances have repeatedly impacted the forest region throughout ancient and modern history [34], attesting to their resiliency.

Compared to other conquered regions in Latin America, early colonial impacts on forest and peoples of the Yucatan Peninsula were distinctly shaped by a dearth of natural resources of value to the Spaniards [36]. The lack of precious metals, scarce surface water, and shallow karstic soils occasioned limited

commercial interest. During colonial times, and well into the 18th and 19th centuries, the forests of Quintana Roo were exploited by the Spanish, the British, and later, American companies to export forest products such as dyewood (*Haematoxylon campechianum*), mahogany (*Swietenia macrophylla*) and chicle or chewing gum derived from the resin of the chicozapote tree (*Manilkara zapota*). Apart from these products, forests in Quintana Roo were primarily regarded as a hostile and largely unexplored frontier region, providing a safe-haven for fierce Mayas, pirates and smugglers well into the early 1800s [37]. From 1847 to 1901, the Caste War ensued, exacerbated by a Maya uprising against the creole henequen plantation owners in northern Yucatan Peninsula. The forests of Quintana Roo were employed for jungle-guerilla warfare tactics by the rebel Mayans, who smuggled and traded valuable forest products with the British of Belize, in return for weapons and other resources to fuel the war against the Federal forces defending the region for the Yucatec creole elite [38]. Soon after the Caste War, a land-tenure framework favorable to common property management arose from the 1910–1917 Mexican revolution [8], enabling the first communal land grants or ejidos to be established in the territory of Quintana Roo in the 1930s and 1940s; these were large ejidos primarily established for chicle and timber production.

Despite land ownership by communities, from the 1950s to 1980s parastatal and private concessions controlled timber production, executing unsustainable harvest levels. It was not until passage of the 1986 Forest Law that communities across Mexico garnered legal rights to the trees on their lands. This precipitated a shift from timber harvests via industrial concessions to community-based forest management. In Quintana Roo, in particular, this shift was accompanied by an innovative Forestry Pilot Plan "to empower ejido residents and increase the economic returns they receive from the forest" [39]. Since, community-based forestry has figured prominently in Quintana Roo, serving as an important economic activity for many ejidos through the late 1990s [40]. By 1995, CFM was consolidated, and Quintana Roo boasted some of the world's first certified forests, placing the state's forestry ejidos and their CFM practices into the global spotlight.

2.2. Biophysical Conditions

Today, the tropical landscape of Quintana Roo can be described as a mosaic of lowland and upland forest types at different successional stages [19,41]. Tropical forest ecosystems dominate the landscape [42,43] of Quintana Roo. These ecosystems lie atop a karst and rolling topography with elevation ranging from sea level to 300 m in the most southern portion of the state. The climate is hot and subhumid, with a mean annual precipitation of 1200 mm, and a pronounced dry season (<60 mm of rain per month) from November to April [44]. Forest types vary according to soil, topography and local climate: medium-stature forests (15 to 25 m) are distributed on well-drained rendzinas, while lower-stature forests occur on seasonally inundated depressions with poorly drained gleysols and vertisols [45,46].

Forest structure consists of three to four shrub and tree layers that range from 3 to 25 m in height [47,48], and there are around 100 tree species per hectare, of which about 75% are evergreen and the rest deciduous [47,48]. Common tree species include *Brosimum alicastrum*, *Manilkara zapota*, *Talisia olivaeformis*, *Bursera simaruba*, *Lonchocarpus longistylus*, *Nectandra salicifolia*, *Psidium sartorium*, *Guettarda combsii*, *Vitex gaumeri*, *Caesalpinia gaumeri* and *Lysiloma bahamensis* [44,48], and *Hemotoxylon campechianum* and *Metopium brownei* in flooded lowland forests, although both upland

and lowland forests share many of the same species [41,49]. Over half of these species are commercial timber species and are relatively abundant [43,46].

Research has described the regenerative capacity and rapid succession of these forests after different disturbances, maintaining its diversity and composition of valuable tree species [50–55]. The high degree of recovery of these forest ecosystems from hurricane impacts has been described by several studies [51,56–58]. Valdez-Hernández *et al.* [50] indicate that five years following disturbance, including felling and slash and burn treatments, floristic diversity was similar to original vegetation. Additionally, Negreros-Castillo and Mize [55] report successful regeneration of commercial species following greater percentages of overstory removal. Mahogany, in particular, has garnered significant attention as a key timber species that occurs at greater densities in the Yucatan Península than other areas within its large geographical distribution in Latin America [59]. With this species, the creation of larger canopy gaps from 2500 to 5000 m^2 also created more favorable conditions for regeneration and growth [53,54]. The abundance of such high-value timber species coupled with ecologically resilient forests, has favored an historical emphasis on management for timber.

While forest loss has been the general tendency in Mexico in the past four decades, forest cover has largely been maintained in the state of Quintana Roo, comprising over 80% of its territory [60,61]. Communally managed forests have contributed to forest conservation and low deforestation rates [19,20,22], with designation in the mid-1980s of large tracts of permanent forest areas owned and managed by rural communities regarded to be a primary reason [19,22,62]. However, forest cover maintenance can also be attributed to the underlying poor soils that dominate the state, which limit the expansion and distribution of commercial agriculture and animal husbandry, activities that commonly lead to forest conversion elsewhere. Environmental limitations to agricultural development dictate that many marginalized rural communities in Quintana Roo turn to their forests to generate income. Still, even though historical and biophysical factors (for example, soils and richness of valuable species) have played a supporting role in the establishment and ecological and economic viability of CFM in Quintana Roo, they are certainly not the only factors at play. Following we discuss how policy and institutions are strongly involved in the development of CFM in Quintana Roo.

2.3. Institutional Factors

Mexico's agrarian reform, which allocated ejidos to thousands of rural communities in the decades following the Mexican Revolution (1910–1917), is often cited as the fundamental institutional catalyst for formalization and continuity of community-based natural resource management (common property management) in Mexico. As a result, nationally, more than half of Mexico's forested lands are under communal ownership [6,63]. In Quintana Roo, some 62% of forests are communally held, based on current figures of forest cover [64].

Ejidos were established in two waves in Quintana Roo. The first occurred during the administration of Cardenas (1934–1940), who championed the idea of cooperativism and viewed the ejidos as the ideal vehicle to integrate indigenous people in the project of the revolution. In 1936, seven large forestry ejidos, averaging 35,000 ha, were established allocating 420 ha of forest for each ejido member for the purpose of chicle harvesting [65]. A second wave of ejidos was created in the 1960s through the 1990s with the objective of stimulating agricultural production, while at the same time encouraging colonization and

relieving pressure from other parts of the country with limited land for redistribution [22,66]. These ejidos were much smaller in size, averaging just 20 ha of land per community member, and were populated by mostly non-indigenous settlers from other states [21]. Today there are 279 ejidos in the state [64], of which 87 have been involved in forest management since 1984, and 55 have active management plans [67,68] (Figure 1).

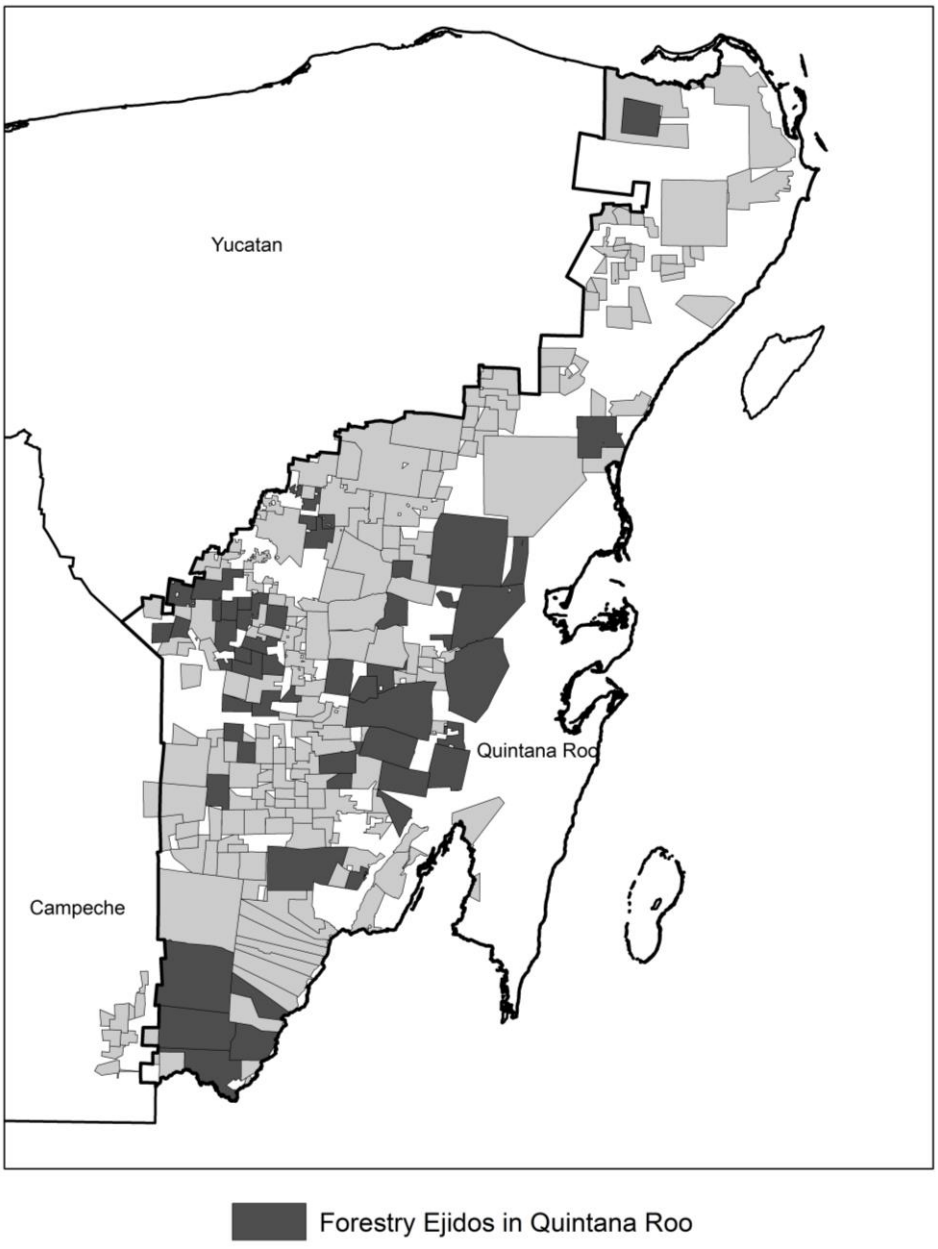

Figure 1. Location of forestry ejidos in Quintana Roo with active forest management plans in 2013.

In addition to establishing collective ownership as a formal land tenure regime in Mexico, the agrarian reform process codified community governance systems modeled after indigenous and colonial systems. These systems have adapted over time, but important characteristics have endured, including their general structure and the way in which they are nested within formal governance systems at municipal, state and national levels. Within each ejido, the General Assembly (GA) includes all authorized ejido

members and is responsible for deliberating community decisions, ranging from natural resource management to ejido membership. The ejidal commission, made up of a president, secretary, treasurer and oversight council elected by the GA for three-year terms, carries out and enforces the decisions made by the GA and provides mechanisms for internal audits and conflict resolution [69].

While the early experiences of the agrarian reform were important in establishing the base for common property management, two key institutional changes in the 1980s consolidated CFM development in Quintana Roo; (1) the 1986 Forest Law that gave communities across Mexico greater legal rights and management control of community held forests and forest resources, and (2) the innovative joint Mexican-German Forestry Pilot Plan (PPF) program initiated in 1983 that developed and strengthened community forest enterprises (CFEs) and helped foster second-tier or civil society organizations to continue supporting CFM. Up until the 1980s, despite collective titles allocating access, use and management rights to ejido lands, communities did not have complete control of their forest resources. The government had the right to award logging concessions on ejido lands, typically to industrial companies. Under these arrangements, communities received few, if any, monetary benefits, usually a small rent or entry fee called "derecho de monte" unrelated to timber volumes extracted. In Quintana Roo, the parastatal company Maderas Industriales de Quintana Roo (MIQROO) controlled about 550,000 ha of forest concessions for a 25-year period, profiting from the overharvesting of about 400,000 m^3 of precious timber, mostly mahogany and Spanish cedar (*Cedrela odorata*) [70,71]. While MIQROO was by far the most important concession holder, other smaller private less structured concessions also were granted in the state.

The shift toward community control over timber originated in the mid-1960s with grassroots mobilizations that sprang up across Mexico, demanding peasant rights to manage and profit from commercial timber on ejido land. In Quintana Roo, for example, the ejidos of Tres Garantías and Noh-Bec were among the first that organized against MIQROO in the 1970s [6,70,71]. Academic activists and even government reformists supported these grassroots movements—all instrumental in the transition from concession logging to community-based forest management [6,72]. The expiration of the contested forestry concessions provided an important window of political opportunity, allowing an alternate proposal for greater devolution of control to communities. Ultimately, the 1986 Forest Law definitively ended private concessions, required more environmentally sound forest management and harvesting, and allowed communities or community organizations direct control of management and marketing of forest timber resources on ejido land [69,71].

As the timber concessions expired and as political momentum grew for greater local control of forest resources, parallel innovations among international donors established enabling conditions for community forest management in Quintana Roo. In 1983, multiple institutions, including the German Society for International Cooperation, formerly known as GTZ (Deutsche Gesellschaft für Internationale Zusammenarbeit), foresters and government agencies, created the PPF. The PPF received strong support from the then Governor Pedro Joaquin Coldwell who recognized the importance of forestry development in the state [72]. The main objectives of the program were to establish permanent forest areas within communities and to develop technical and organizational capacity needed to support CFEs for the sustainable harvest and marketing of forest products. The program's reach was extensive, with 50 member ejidos and over 250,000 ha voluntarily established by communities as permanent forest areas in central Quintana Roo alone [21].

The creation of second-tier forestry organizations, while not the original intent of PPF, remains an important PPF legacy. Originally, groups of foresters were assigned to work with ejidos, providing technical services for the management of permanent forest areas, as well as assisting ejidos in the harvest, processing and marketing of timber. Post-management services were especially critical to increase CFE competiveness, especially as MIQROO was still actively buying and processing timber through the 1980s. As the PPF expired and government funding for forest technicians abated, these groups of foresters either became independent or formed second-tier organizations, also called civil societies. Examples include the Society of Forest Ejido Producers of Quintana Roo (SPFEQR) in the south and the Organization of Forest Ejido Producers of the Maya Zone (OEPFZM) in the central part of the state [70,71]. In addition to providing necessary technical forestry expertise, these second-tier organizations played an important role in organizing rural communities, empowering ejidos and using their collective action to gain political credibility. For example, in 1987 these organizations were successful in blocking a state government attempt to obligate ejidos to sell timber to MIQROO. More importantly, they laid an institutional foundation to allow continuity of community-based forest management, community enterprises and rural development beyond the pilot plan [70,71]. These organizations, however, have not been immune to problems related to corruption, poor administration, and conflicts with ejidos and among each other [73].

2.4. Socioeconomic Factors

Socioeconomic factors have also been influential in the establishment of CFM in Quintana Roo as production and markets of timber and non-timber forest products are vital to community economic success and survival. In recent years, although the almost $12 million in state revenues attributed to forest production have been equally divided between timber and non-timber products [74], timber has historically dominated the socioeconomic balance sheet. For the past two decades, although the state of Quintana Roo has consistently produced only around 0.6% the nation's total annual timber production [61,75], it has been the second national producer of "precious" tropical hardwood timber (28%, and mostly mahogany), only behind the state of Campeche (32%) [76,77] and the fourth national producer of "common" tropical timber (11%) [62,77]. Of the annual timber volume extracted from Quintana Roo in the past two decades, over 70% is typically represented as common tropical timber while precious timber varies from 15% to 27%. Production of precious timber in the state was drastically reduced with the transition from timber concessions to CFM. Annual harvest volumes of mahogany and Spanish cedar typically ranged between 40,000 and 50,000 m^3 from the mid-1950s to mid-1980s when the parastatal companies led logging activities in the region, and then gradually declined and plateaued between 8000 and 10,000 m^3 in the early 1990s as community members became more actively involved in logging [78]. For the past 25 years, timber volumes originating form Quintana Roo has mostly hovered between 35,000 and 45,000 m^3/year (Figure 2).

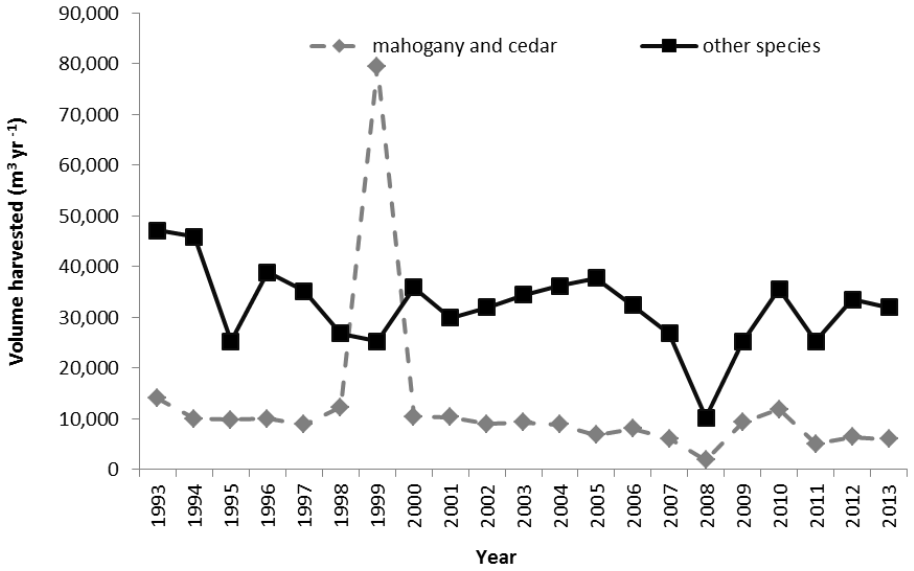

Figure 2. Annual commercial timber harvest in Quintana Roo, Mexico. Timber volumes include all wood uses, such as sawtimber, pulp, veneer, polewood, firewood and charcoal, but excludes railroad ties up to 1995 [79]. The 1999 spike in mahogany and cedar harvest volumes is consistent with other official data, but remains unexplained in these sources. The dip in 2008 is attributed to Hurricane Dean.

Recent figures indicate that over 85% of managed forests and timber production in Quintana Roo originate in ejidos [67]. The principal beneficiaries of the forest economy in the state are the more than 50 ejidos these located mostly in the Mayan Zone of central Quintana Roo in the municipality of Felipe Carrillo Puerto, and in the southern portion of the state in the municipality of Othón P. Blanco [67] (Figure 1). Local economic benefits derived from commercial forestry vary widely among ejidos, partially driven by heterogeneous, native abundance of valuable hardwoods and the size of the forest management area. The number of ejidos involved in legal harvest of forest products has fluctuated over the years, varying from 61 in 1995 to 80 in 2006 [80], 46 in 2010 and 55 in 2013 [81]. According to records from the state CONAFOR (National Forestry Council) office in Chetumal, of a total of 213 ejidos, 60% are categorized as Type I (communities with potential for forest production, but without formalized management); 16% are categorized as Type II (communities with formalized management that sell timber as standing trees to external operators and buyers and do not participate in logging); 19% are categorized as Type III (communities that participate in formalized management and logging activities, selling timber as roundwood), and only 5% are Type IV (communities that participate in formalized management and logging activities, have saw mills, and sell sawnwood and other value-added products). Based on 200 household surveys in six communities, Bray *et al.* [16] reported that two Type IV communities were well above the poverty level. On the other hand, two Maya Type III communities (without sawmills) had household incomes below the poverty level, suggesting a relationship between ethnicity and poverty and the importance of value-added production in improving revenues and livelihoods.

Moreover, timber market chains are complex and vary by species, quality, processing, certification status, machinery ownership and the particular contacts that the ejido or seller may have. For example, mahogany from Noh-Bec may reach regional, national, and international markets (mainly in the US)

requiring high-quality standards, while lower-quality pieces are used for local carpentry and beehive construction [82]. Katalox (*Swartzia cubensis*) is sold in a small European niche market [82], and particular softwood species (e.g., *Dendropanax arboreus*) are sold for production of matches, tongue depressors, and toothpicks [83]. Tzalam (*Lysiloma latisiliquum*) is increasingly sought after for timber, and for many ejidos currently provides their main source of forest revenue. Other highly valuable species have local and international niche markets, such as holywood (*Guaiacum sanctum*), granadillo (*Platymiscium yucatanum*), siricote (*Cordia dodecandra*), and machiche (*Lonchocarpus castilloi*), which feeds a growing flooring market. On the other hand, some species considered internationally as lesser-known species have local markets, such as yaxnik (*Vitex gaumeri*). Markets and exports for secondary products such as furniture, floors and frames have increased, while markets for sawnwood remain constant but considerable, mostly destined for national markets [77]. Polewood, small diameter trees (<35 cm in diameter) of more than 30 species, locally referred as *palizada* [84], has emerged in the last 15 years as one of the state's most important forest products (Table 1). Polewood is commercially harvested mostly as construction material for building thatched huts and other rustic constructions that are ubiquitous features in tourism resorts across the coast. However, more recently, polewood is also harvested for a national market for horticultural support stakes, and is also increasingly transformed into charcoal.

Table 1. Harvested timber volumes per species and harvested volumes as percentage of the authorized timber volumes per species in Quintana Roo, Mexico. Volumes per species are calculated as the average of the years 2012 and 2013 [85,86].

Family	Species	Common Name	Volume Harvested m^3 $year^{-1}$ (2012–2013 Average)	Harvested/Authorized Volume (%)
Fabaceae	*Lysiloma bahamensis*	Tzalam	7796	47.7
Various	Polewood > 30 species	palizada	5424.5	17.4
Sapotaceae	*Manilkara zapota*	Zapote	4380.5	34.2
Meliaceae	*Swietenia macrophylla*	Caoba	4206	72.6
Anacardiaceae	*Metopium brownie*	Chechen	2622	30.0
Burseraceae	*Bursera simaruba*	Chaka	2126	28.2
Araliaceae	*Dendropanax arboreus*	Sakchaka	1221	60.6
Lamiaceae	*Vitex gaumeri*	Yaxnik	550	35.8
Fabaceae	*Piscidia piscipula*	Jabin	320	25.2
Combretaceae	*Bucida buceras*	Pukte	289.5	41.3
Fabaceae	*Swartzia cubensis*	Katalox	284	12.1
Rubiaceae	*Sickingia salvadorensis*	Chaktekok	264.5	17.7
Fabaceae	*Caesalpinia mollis*	Chakteviga	148	8.8
Fabaceae	*Lonchocarpus castilloi*	Machiche	143.5	46.1
Meliaceae	*Cedrela odorata*	Cedro	142.5	86.1
Fabaceae	*Platymiscium yucatanum*	Granadillo	135	41.6
Malvaceae	*Pseudobombax ellipticum*	Amapola	121	7.4
Boraginaceae	*Cordia dodecandra*	Ciricote	37.5	28.6

Table 1. *Cont.*

Family	Species	Common Name	Volume Harvested m^3 $year^{-1}$ (2012–2013 Average)	Harvested/Authorized Volume (%)
Apocynaceae	*Aspidosperma cruentum*	Bayo	20.5	17.1
Moraceae	*Brosimum alicastrum*	Ramon	19.5	9.3
Simaroubaceae	*Simarouba amara*	Pasak	5.5	0.7
	Total		30,257	31.0

Quintana Roo's place in tropical timber production in Mexico, and the available and constant demand in local, national and international markets has made CFM an important economic activity for many rural communities in Quintana Roo. The economic viability and locally-centered benefits obtained from CFM are crucial to its establishment and persistence as a production activity observed in many forest communities.

3. Constraints and Shocks Affecting CFM

Despite the historical, institutional and socioeconomic factors that favored the establishment and consolidation of CFM in Quintana Roo, forest communities have faced diverse constraints and shocks. These include political and institutional reforms affecting CFM support, land tenure and forest governance; socioeconomic constraints such as dependence on limited buyers, markets and investment; and environmental shocks from hurricanes and fires affecting the forest resource base.

3.1. Policy and Institutional Constraints

In the 1990s, the constitutional and legal foundation that provided the unprecedented protection and support for common property ownership and forest management underwent major reforms as the Mexican government sought to decrease government involvement in the rural sector and increase private sector/market-based reforms. The policy changes that most directly affected CFM were trade agreements, dismantling of government support for CFM, and the spawning of the 1992 Forest Law. The most direct impacts of the government's neoliberal turn on CFM was the flood of cheap timber from the US, Brazil and other countries [77,87], facilitated by the 1986 General Agreements on Tariffs and Trade, which in turn resulted in the reduction of government support for CFM, and helped nudge forest management and production back into the hands of industry [69–71,88]. Reduced support of CFM was codified in the 1992 Forest Law, which focused more on developing plantation forestry, eliminated government-supported technical assistance (relegating these services to second-tier forestry organizations and consultants), and, notably, did not distinguish or support community forestry in any way [69,70]. Not only was federal funding stripped for CFM, but in a perverse twist, a government subsidy program to promote land under agricultural production (PROCAMPO) was launched in 1993, which effectively promoted deforestation in the region by incentivizing clearing of forest for agriculture [89,90].

The 1992 reforms to Article 27 allowing for privatization within ejido lands, had and continues to have, the potential for sweeping transformation of Mexico's rural sector, within forested ejidos and beyond. The reforms and resulting new Agrarian Law had two key impacts for forested ejidos in Quintana Roo, potentially constraining CFM's original promise of both environmentally and socially sustainable

development. First, it promoted informal parcelization of forestlands—a process by which the ejido internally divides and distributes ejido lands without undergoing legal titling of individual properties [36,91,92]. While this process may have been occurring in ejidos of Quintana Roo before the 1992 reform, the new agrarian law, in some cases legitimized, and stimulated this informal parcelization.

Research has demonstrated how ejidos have selectively adopted some aspects of privatization, without undergoing the formal process of certifying and titling ejido lands [36,91,93–95]. This research notes how ejidos internally and informally divided common forest areas, including permanent forest reserves established during the PPF, and converted them to individual landholdings. This had a range of results; in some cases, ejidos lost timber authorization and subsequently forest parcels were converted to agriculture. In others, ejidos continued forest management as individual enterprises with few benefits of economies of scale outside the legal framework established by the Secretariat of Environment and Natural Resources (SEMARNAT). Finally, recent research among eight ejidos in the region demonstrated that informally privatized ejidos had higher deforestation rates, while commonly-held ejidos were more effective at forest conservation, especially in cases where forests provided economic benefits to ejidos via timber management [92].

The second broad impact of the reforms on CFM was the sanctioning of joint ventures between groups of ejidatarios and external actors (Article 75 of the new Agrarian Law), which facilitated the proliferation of CFM sub-groups or work groups within forestry ejidos [71]. Prior to the 1992 reforms, governance and organization of CFEs generally mirrored the broader structure of ejido governance in which the elected ejidal commission administered communal forest enterprises, with equal distribution of forest revenues to ejido members, and in many cases a portion of the profits were destined for re-investment or community infrastructure or emergencies. Article 75 allowed ejidatario producer subgroups to operate as independent commercial entities separate from the elected ejidal commission [70]. In the economically important forestry ejidos of Petcacab and X-Hazil, this division of the ejido community forest enterprise has led to multiple (10 or more) work groups [69–71,96].

Wilshusen [97] demonstrates how the formation of work groups in Quintana Roo has the potential to undermine social capital within ejidos and result in unequal distribution of CFM benefits. For example, elite work groups may flourish and obtain greater rewards from forest management due to better networking, access and management of financial capital, and influence in the community. Further, a highly fragmented CFE within ejidos may not benefit from the economies of scale or collective power for obtaining finance or negotiating with buyers [70,71]. Further studies to assess the impacts of workgroups on CFM in Quintana Roo are sorely needed.

Additional changes to ejido governance instigated by the new Agrarian Law include the sanctioning of the acquisition of ejido rights by people from outside the communities. Notably, this has resulted in an increased number of outsiders purchasing ejido membership rights in particularly profitable forestry ejidos such as Noh Bec and Petcacab. In some cases, this has brought additional investment and technical skills to ejidos, while at the same time, has generated conflict and governance challenges. The market for ejido land rights has also spurred the use of ejido membership rights as loan collaterals, which has resulted in the accumulation of ejido membership rights by local elites (e.g., local lenders, shop owners and timber buyers). In addition, as a result of the new Agrarian Law, there is an increasing number of non-ejido members allowed to vote in general assemblies [98]. This has important ramifications for ejido

governance and decision-making as ejido demographics change, shifting from an aging population, to a younger population, increasingly from outside the region.

3.2. Socioeconomic Constraints

Trade agreements since the mid-1980s, such as GATT in 1986 and NAFTA (North American Free Trade Agreement) in 1994, have had considerable impacts on Mexico's forest sector. Since NAFTA, import and export tariffs were completely eliminated for roundwood, sawnwood and other wood products, resulting in increasing imports particularly for secondary processed wood products. Chapela [99] describes how the trade deficit has caused a loss of competitiveness for CFEs creating difficulties to access international markets as well as maintain their place in national markets. Mexican trade deficit of sawnwood derived from tropical timber is shown in Figure 3.

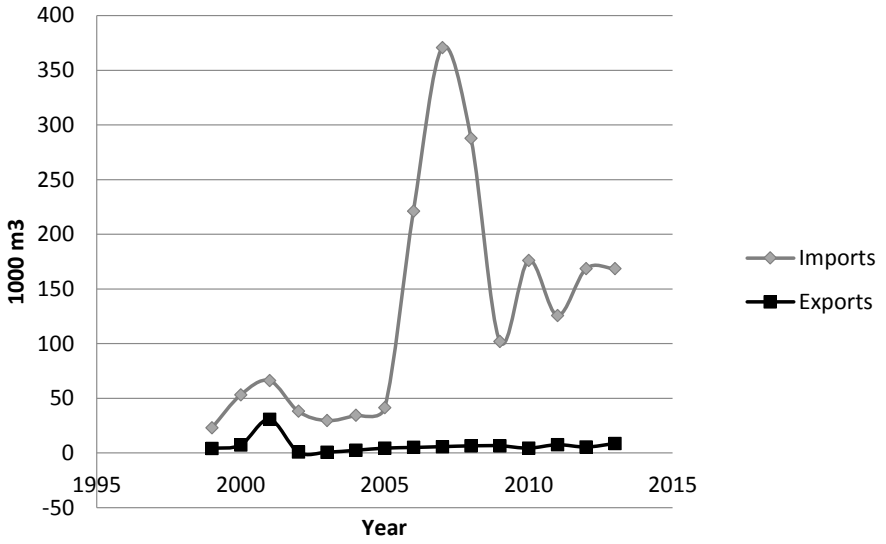

Figure 3. Mexican annual imports and exports of sawnwood from non-coniferous tropical species [87].

Communities with timber management in Quintana Roo have had to endure a suite of production, marketing, and economic constraints affecting the development of effective CFEs with improved value-added production and marketing capabilities. The degree of timber production, value-added timber processing, and marketing capabilities varies greatly among ejidos in Quintana Roo. All ejido communities have land rights and the final say in forest management; however, involvement of private actors and companies in management and commercialization is increasingly present, and the degree of involvement varies as well. In many cases, local companies and individuals conduct logging operations, operate sawmills, and commercialize forest products; in others, ejidos possess an integrated vertical structure, participating in all the aspects of forest management from planning and harvesting to commercialization of processed products [82]. Still, in Quintana Roo the majority of timber produced in ejidos is bought as roundwood by a handful of buyers, which largely dictate the timber demand with regards to species and volumes. Presently, only around 25% of communities who manage forests for timber are directly involved with harvesting while the rest outsource these services to local buyers [77]. For many communities, dependence of outside local private companies for timber purchases, harvesting

activities and transportation greatly diminishes economic benefits and their ability to invest in value-added production such as milling. Additional unfavorable CFE conditions include high import rates of tropical timber [77,87], almost a complete lack of investment from the public and private sector, and for Type IV forest communities, sawmills and machinery that are increasingly obsolete and in poor condition [77]. This dearth in investment in CFEs may also result in the limited number of timber buyers in the region, limited mostly to wealthy sawmill owners with better capabilities such as drying kilns and wood quality control. In Quintana Roo, the private enterprise Productos Forestales del Sureste y Centro America S.A. de C.V. with more advanced milling, value-added capacity, and chain of custody certification, is clearly an influential, yet often overlooked, actor in timber products commercialization and CFM in the region. Almost 60% of the timber produced in the state is directly sold to wholesale intermediaries with large sawmills, such as the one described above [77].

Volumes extracted from Quintana Roo ejidos engaged in timber management typically ranges between 15% and 30% of the authorized harvest volume pre-approved by SEMARNAT, showing potential for more production and suggesting limited market demand [67]. While the market is increasingly embracing a higher diversity of timber species, demand is still narrowly concentrated on only a few. For example, *ca*. 73% of the authorized volume of mahogany is harvested, contrasting with pasak (*Simarouba amara*) where less than 1% of its authorized volume is harvested (Table 1).

In rural Mexico, access to formal credit through banks and credit unions is limited. Credit is particularly restricted for the forestry sector [77], which accounts for only 0.88% of the primary-sector credit and is mainly represented by loans for commercial forest plantations [100]. In this context, individuals rely mostly on informal credit through moneylending, tandas (rotational credit associations), and pawning [101]. In other cases, advances or loans to conduct harvesting are provided directly by the timber buyer, ensuring their supply of timber for local, national and international markets [67]. The entrepreneurial structure of forest management, (e.g., communal enterprise, working groups, or individual entrepreneurs) also influences access to particular subsidies, credits, or grants.

In addition, local socioeconomic constraints faced by CFEs are related to lack of skills and training in business management, marketing and value-added production. Knowledge of and access to a more diverse suite of buyers for different wood products is needed. Basic capabilities in accounting and record keeping are lacking for many ejidos, which often leads to monetary losses, corruption and mismanagement of forestry loans and profits. Moreover, wood products, typically sawnwood, produced in community sawmills require certain characteristics depending on the client and end product. Lack of local capabilities in wood classification, advanced processing (for example, drying, edging and planning), and supplying proper lumber dimensions are additional marketing and economic constraints to the development and success of CFM.

3.3. Biophysical Shocks

Forest ecosystems of the Yucatan Peninsula are often subjected to major biophysical shocks due to frequent impacts from hurricanes and fires. Average return frequency of hurricanes making landfall in Quintana Roo in the last century has been every four years. From 2005 to 2010, 12 hurricanes crossed the Yucatán Peninsula, the majority entering on the eastern coast of the state [56,102], with Emily and Wilma in 2005 and Dean in 2007 causing severe damage to forest vegetation [51,56]. More than 50% of

the stems in a post-hurricane site can present significant damage from uprooting or snapping and can result in close to 100% defoliation [51,56–58]. Hurricane impacts may be greater in forests managed for timber, since harvesting creates openings (*i.e.*, logging gaps, skid trails, logging roads, log landings) that make forests more susceptible to wind damage [46].

Hurricane Dean in 2007 took a heavy toll on forest communities in central Quintana Roo, drastically altering timber production and forest management plans and activities. Major timber-producing ejidos, such as Noh-Bec and Petcacab, were severely impacted by Dean as were other Mayan ejidos such as Santa Maria Poniente Laguna Kanab and Naranjal Poniente. While official statistics capture one set of harvest dynamics (Figure 2), localized data from the three most important mahogany producer communities (Noh Bec, Petcacab and Tres Garantías) provide alternative insights (Figure 4). In Noh Bec and Petcacab, Dean's impact was followed by an unprecedented spike in mahogany salvage harvests followed by a significant decrease in harvests. On the other hand, in Tres Garantías, a community not impacted by hurricane Dean, mahogany harvests remained stable over time. Furthermore after hurricane Dean in 2007, tzalam, and chicozapote surpassed mahogany as the most harvested timber species in the state (Table 1). The emergence of chicozapote, the most culturally and historically important NTFP species in the region, as a major timber species represents a significant change in forest management that requires further examination.

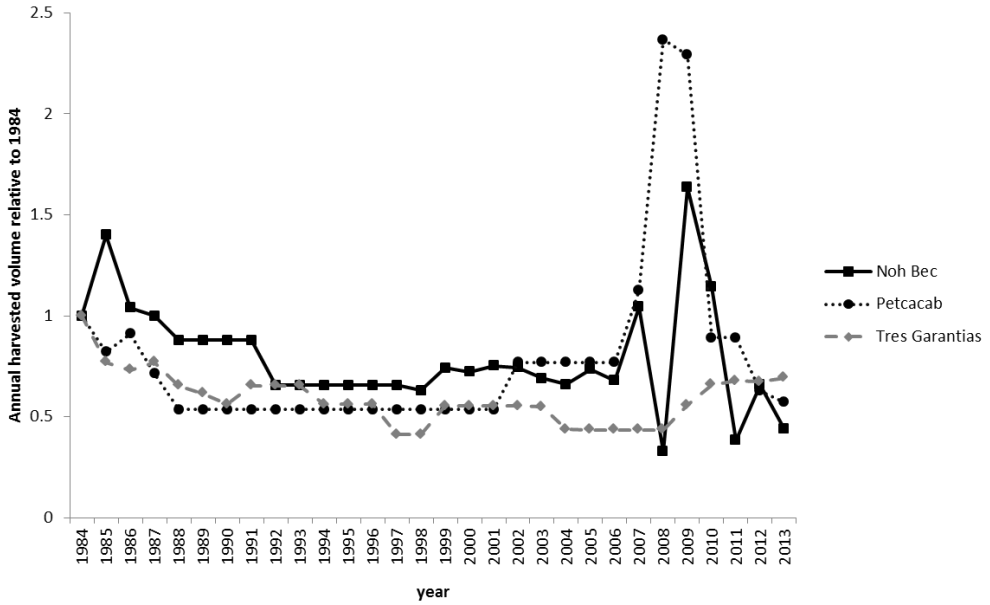

Figure 4. Annual precious timber harvests relative to 1984 volumes for the three communities with the largest timber production in Quintana Roo, Mexico (1984 to 2013). Precious timber includes big-leaf mahogany *Swietenia macrophylla* and Spanish cedar *Cedrela odorata* [85,86,103–105].

Hurricanes also exacerbate forest fire incidence, and fire stands out among the principal drivers of forest cover loss in the Yucatan Peninsula [102]. Downed plant material created by hurricanes dry quickly in enlarged gaps, making these forests more susceptible to fires during the dry season [43,46], fertility could decrease, reducing forest recovery [51]. CONAFOR [106] reports that in 2009, Quintana Roo was the second-ranked state with the most surface area affected by fires, totaling 42,350 ha.

Hurricanes seem to also precipitate regulatory action. Previously-approved management plans have been cancelled by the Secretariat of SEMARNATin ejidos where forest management areas have been impacted by hurricanes, because the inventories and calculated volumes were assumed to have been altered and were therefore invalid. After Dean, many of the affected timber-managing ejidos had to submit new and special management plans to SEMARNAT to salvage logs and clean up dead and fallen wood. In turn, this led to the loss of FSC (Forest Stewardship Council) certification in some cases, since accrediting bodies did not accept these special temporary management plans [107]. Indeed, the overall ecological and socioeconomic disturbance from Hurricane Dean interrupted certification renewal of various ejidos, reducing the number certified within the state [107]. In sum, the added post-hurricane bureaucracy and lengthy time involved to resubmit management plans resulted in a significant loss of valuable timber and increased risk of fire from accumulated debris and rotting logs that remained in the forest [67].

4. Adaptation of CFM in Quintana Roo

Even though community-based forestry in Quintana Roo has faced a variety of both institutional and socioeconomic constraints, it has also proven to endure, adapt and survive. Literally and figuratively, it has been able to ride out the storms of biophysical shocks as well as major policy shifts and changing forest economies and markets. The way CFM has responded has been explained as resembling an adaptive management approach [23,29,31], although, in Quintana Roo this has not been a conscious or deliberate process by the different actors involved [23]. Still, forest communities and institutions are described as undergoing a learning process, which combines both local and external knowledge to respond and adapt to changing environments [23,29,31]. In this section we examine how forestry institutions and communities have responded and adapted to these challenging political, socioeconomic and environmental events.

4.1. Role of Policy and Institutions in Adaptation

Institutional arrangements, products of years of policy reforms and forest-based development initiatives, helped shape a socioeconomic landscape apt for the continuity of community forest management. These arrangements have also broadened the focus of CFEs from timber extraction to include forest product diversification, payments for environmental services (PES), and eco-tourism as part of integrated rural development strategies. As a response to the 1992 Forest Law which eliminated government support for forest technicians, increasingly common in the region has been the rise of individuals providing technical forestry support to ejidos (*i.e.*, 38 freelance consultants and eight firms) who are now registered in Quintana Roo [108], and may or may not be affiliated with second-tier organizations. These private technical consultants support themselves largely through government programs that are channeled through ejidos for this purpose, by volume-based commissions per ejido, and through obtaining external funding to carry out community projects akin to fundraising strategies adopted by NGOs. Forest technicians in Quintana Roo play a crucial role in the administrative processes and technical requirements for forest management by ejidos, and ejidos are highly dependent on their services as intermediaries between government regulatory and funding institutions (SEMARNAT and CONAFOR). Other than forest management and production, government programs include funding for

PES, ecotourism development, or land use zoning and planning in ejidos. In many cases, communities participate in different government programs due to the liaison between independent technical consultants or forestry technicians working with second-tier organizations. Furthermore, second-tier organizations, such as OEPFZM and SPFEQRO, have allied ejidos and provided technical support personnel who fundamentally facilitated community access to government forestry programs and compliance with the many and complicated forest-management legal requirements.

Reforms of the 1992 Agrarian Law also brought about major changes to CFM that resulted in adaptive responses by forestry communities and institutions. As described above, Article 27 brought threats of privatization and deforestation within ejidos to the region. However, in some cases, ejidos engaged in CFM saw privatization, albeit informal, as a way to resolve internal conflicts and management problems, including illegal timber harvests [36,91,92]. While many speculated that the 1992 reforms would lead to widespread privatization, less than 10% of ejidos nationwide have opted for formal privatization [109]. In Quintana Roo, the vast majority of ejidos (98%) chose only to certify common-use lands via the federal government's Program of Certification of Ejido Rights and Titling of Urban Property (PROCEDE), whereby individual ejiditarios receive certificates to their share of land in agricultural and urban areas. The major ejidos with CFM maintained forest areas as common property regimes and converted only agricultural lands to quasi-private land holdings. The low privatization rate is, in part, due to an important clause in the reforms that prohibited the division and alienation of commonly held forest lands (Agrarian Reform, Article 59), although it is important to note that low adoption of individual titling may be also attributed to fear of the high bureaucratic costs entailed and increased taxes, among other concerns [36]. While the relationship between tenure regimes and forest management outcomes is yet to be definitively analyzed (see, for example, Casse and Milhøj [110]), there is general consensus that Mexico's communal land grant system has been an important facilitator and institutional bedrock of CFM in Mexico. Therefore, further inquiry into the impacts of forest tenure and forest cover in Mexico following the reforms is needed.

Moreover, through Article 75 of the reformed Agrarian Law in 1992, the forest governance structure of ejidos became modified when some ejidos in Quintana Roo opted to create working groups, which fractioned the community into even smaller groups of ejido members harvesting timber [111,112]. In these cases, an ejido's General Assembly (GA) allots a specific amount of SEMARNAT authorized timber volume according to number of ejido members within a working group [107]. Each group contains their own elected positions, rents or owns machinery, and are granted specific plots in the annual cutting areas through a lottery system overseen by the GA. Additionally, each group is responsible for finding timber buyers while all of their timber volume sold must be registered through the Ejidal Secretary. This occurs in at least 10 ejidos in the state. While the formation of workgroups has been described above as having a negative impact on CFM, in some of the ejidos in Quintana Roo, particularly with a small number of workgroups, they have been a successful adaptation to date. One ejido that differs in their forest governance structure is the ejido of Noh Bec. They have a separate forestry office that includes community forest technicians responsible for forest inventories, environmental impact monitoring, overseeing logging practices in the field, as well as procuring buyers [107]. This separation of logging supervision ensures local capacity-building of forest technicians from the ejido, improves buyer relations by demonstrating their community forestry enterprises' stability in maintaining long-term personnel who continually interact with buyers and know their preferences, and while also ensuring a balance and

checks is in order by the technicians and employees complying with ejido rules (*i.e.*, submitting administrative and financial reports to the GA).

In addition, agricultural development policies, such as PROCAMPO in 1993 and PROGAN (Program for Cattle Production Development) in 2007, have also threatened deforestation and CFM in in the region [89,90]. Research has shown that the impacts on deforestation as a result of PROCAMPO (or PROGAN) vary. For example in neighboring Campeche, specifically the Calakmul region, ejidos were deforesting in response to these subsidies for agricultural production [90,113], however, in regions where ejidos with CFM are prevalent, such as the municipality of Felipe Carrillo Puerto in Quintana Roo, these programs appear to have no relationship on deforestation, which has a low rate to begin with [113]. Due to strict land use zoning and regulations in forestry ejidos, they maintain PFAs with mature forest and permit production activities only in agricultural zones via fallow rotations every 5 to 12 years [19,20].

Even though neoliberal policies in the early 1990s were stifling to CFM and CFEs in Quintana Roo, key policy and institutional changes since 1997 have helped facilitate adaptation by forestry beneficiaries and have also transformed CFM in the region. These shifts responded to environmental concerns particularly of deforestation, and once again recognized that CFM was key to forest conservation and sustainable rural development. The 1992 Forestry Law was renewed in 1997 and later reformulated in 2003, providing more support to CFM. For example, the 1997 Forest Law provided measures to regulate management of natural forest, bring avenues to support community forestry, and promote new incentives for plantations, creating three new programs for these purposes, PRODEFOR (Forestry Development Program), PROCYMAF (Community Forestry Development Program), and PRODEPLAN (Forestry Plantation Development Program), respectively [70]. The 2003 Forest Law created the National Forest Commission (CONAFOR), and included a 10-fold budget increase in the PROCYMAF program directed particularly to community forestry in several states, including Quintana Roo, the major recipient of these funds [69]. More recent programs that have continued supporting community forestry development include ProArbol in 2007 and later PRONAFOR in 2013.

In sum, various government programs provide incentives to individuals, communities, or organizations that may cover a range of activities: agricultural and animal husbandry improvements, agroforestry, fire prevention practices, payments for ecosystem services, payment to technical consultants for local capacity-building and management planning, or infrastructural investments. For example, as of 2011, ejido members who were trained and certified through CONAFOR's nationally funded "Community Technicians Course" are allowed to legally provide technical forestry assistance within ejidos and to directly access CONAFOR funds to do so. This is a new attempt by a national government institution to strengthen local community participation and benefits from forest management. To different extents, most forest communities do capitalize from government programs in Quintana Roo and have become quite adept at tapping into these resources. Some ejidos like Noh-Bec have received large national and international grants.

4.2. Socioeconomic Factors and Adaptation

Forest communities in Quintana Roo have adapted to socioeconomic constraints through a variety of strategies. Despite the economic hardship and unfavorable timber prices in the 1990s, ejidos such as Noh-Bec and Laguna Kan á willingly reduced logging volumes by more than 30% to sustain production

over the long term [69]. Others have paid higher prices for technical services—all with a genuine desire to progress in sustainable forest management [70]. In addition, mid to long-term effects of changing forest economies have been the pursuit of value-added and diversified production by CFEs [99]. CFEs in Quintana Roo have been able to bank on Mexico's strengths in the forest products market, specifically supplying niche markets for high-value tropical hardwood products, and some once again acquiring FSC certification.

Diverse efforts have been made to upgrade the market position of local producers. One example is a timber-marketing fund established with federal monies to secure higher prices and to find national and international outlets for lesser-known timber species [97]. The Consorcio Chiclero is an initiative that resulted from the merging of the chicle-tapper cooperative movement with the Plan Piloto Chiclero, a product (or outcome) of the Forestry Pilot Plan [114]. Nonetheless, the production and economic benefits of chicle and other NTFPs are currently minimal in Quintana Roo. Forest management certification was another marketing initiative of the early 1990s in which 11 communities began the FSC certification process but only eight actually obtained it [82]. While ejidos in Quintana Roo and Oaxaca, Mexico were the first communally managed forests to be certified, only ejidos that were also able to obtain chain of custody certification and to export timber received premiums for certified timber, therefore making certification economically viable [82].

While forest certification can be seen as a market mechanism to improve forest management, its long-term viability can also be affected by institutional policies. Certification implementation was also heavily supported by the state government of Quintana Roo from 1999 to 2011, as demonstrated in the state's forestry sector development plans for the two five-year periods. Afterwards, institutional support at the state level lulled for timber certification but at a national level Mexico saw a renewed interest in forest certification through its relevance to future carbon credit and REDD (Reducing Emissions from Deforestation and Degradation) inititiaves. In 2011 the United Nations Development Program (UNDP), Rainforest Alliance and CONAFOR partnered together to increase forest certification and timber production within ejidos in the peninsula as well as at a national-level and is still functioning. An important local alliance between five large forestry ejidos that was created out of this initiative is the Southeastern Ejido Alliance, which is now legally able to receive funds to support their forest management studies affecting 114,000 hectares of forest in Quintana Roo and benefitting over 1200 ejido members. Adding value to forest products has been an important strategy promoted by forest civil societies and NGOs and has included on-site milling with micro sawmills and wood-based handicrafts [115]. A current example of this is the Rainforest Alliance's TREES program focus on production improvement for small and medium scale community forest enterprises through certification and the use of portable sawmills in the Mayan Zone of Quintana Roo in 2015. Impacts of myriad marketing initiatives are diverse, and in many cases, it may be premature assess their success.

The provision of ecosystem services at the local level (soil enrichment, watershed protection and conservation of biodiversity) has ensued in their external valuation via PES (Payment for Environmental Services) [116]. Increasingly, since 2005, both timber-focused and non-timber ejidos have been setting aside additional forest land under PES programs sponsored by CONAFOR, both for hydrological and biodiversity purposes [117–119]. Some ejidos, such as Yoactun, currently receive more income from PES than from timber sales and many ejidos in the Municipality of Jose Maria Morelos have opted to designate their land to the PES program instead of logging due to its profitability [115,120].

Moreover, communities such as Naranjal Poniente have set aside voluntary conservation areas in addition to PFAs, an increasing trend observed in ejidos [116]. Others, such as Betania and Noh-Bec, are involved in multiple-use forest management with areas set aside for ecotourism and biodiversity conservation, in addition to forest for timber production. Increased interest in ejidos to use timber waste from logging for charcoal production is also being explored by individuals, and most recently in Noh Bec. Pole-sized trees also exemplify adaptation as product demand from this size class has shifted from railroad ties to construction materials. Known simply as polewood, this most recent commercial product is derived from more than 30 hardwood species and is used mainly for construction material demanded by the tourism industry [88]. In communities where timber and polewood volume rights are distributed among ejidatarios, if an emergency need arises, volume rights can be sold beforehand at reduced prices to local elites [121]. These adaptive strategies of multiple forest use, land-use zoning, and diversification of forest income sources show promise in the region as local community adaptations respond to national and global forest conservation initiatives.

4.3. Responses to Biophysical Shocks

Climate variability and biophysical shocks, such as drought, have been linked to major shifts in socio-cultural development in the Yucatan Peninsula [122–124]. Hurricane Dean, a category 5 storm that made landfall in Quintana Roo in 2007 damaging approximately 22,000 km^2 of forests [125], provides an apt example to examine the response of forestry communities and institutions. Many communities that were dependent upon forest management for their livelihoods needed to devise short-term coping strategies for income generation as well as longer-term vision for community development. Secondly, hurricane damage generated significant uncertainty among local level institutions as well as state-level environmental and natural resource agencies (SEMARNAT) regarding the viability of pre-hurricane management plans.

In response to the immediate impact of downed logs, many communities organized brigades to remove forest debris and salvage timber, using the same institutional structures (e.g., work groups) to quickly mobilize human resources in the community [126]. In some cases, local communities implemented bans on burning for agricultural lands to reduce fire risk, again building on existing arrangements for rule-making and sanctioning for forest management [126]. At the state-level, key officials, building upon experience with Hurricane Wilma in the Yucatan, implemented a provisional regulatory framework to extract dead trees, called "simplified management plans" (NOM-152 SEMARNAT) [126]. These plans allowed ejidatarios to legally extract fallen trees and as a result, reduced forest fuel load and reduced fire risk. Simplified management plans were approved for short periods of about three months (eligible for renewal) while SEMARNAT faced the challenge of controlling the harvest of damaged timber and avoiding the illegal harvest of standing trees [126]. Despite local institutional arrangements and state-level innovation, some communities, especially those with weak local governance structures, took advantage of the situation to engage in predatory and haphazard logging of damaged forests [126] and state agencies lacked capacity to control illegal harvests and provide adequate guidance for salvage of fallen timber with minimal damage to remaining forest stands [127].

Hurricane Dean was a learning experience for communities and institutions involved in CFM in Quintana Roo. Forestry communities became more aware of the particular vulnerabilities of community

forestry enterprises; in some cases, prompting communities to consider more diversified livelihood strategies, as well as longer-term adaptation strategies to increasing risk from climate variability, including alternative forest-based incomes, such as PES. In their study of forestry communities following Hurricane Dean, DiGiano and Racelis [126] identified institutional memory, the resource bank of previous experiences with adaptation and communal management of resources, as an important source of adaptive capacity and resilience to shocks among community forest enterprises. In addition, the hurricane prompted research into better silviculture practices to reduce severe weather event impacts. For example, the study by Navarro *et al.* [128] concluded that reducing the concentration and number of log landings could potentially reduce damage, and further recommended that management plans should include aspects on harvesting damaged trees as well as monitoring after severe weather events. Given that hurricane frequency and intensity is expected to increase with warming ocean temperatures [129], forestry communities and supporting state institutions must continue to design and deploy a range of adaptive strategies, ranging from forest management and institutional innovations, to increase resiliency to biophysical shocks.

5. Future Challenges for CFM in Quintana Roo

Forest communities and institutions in Quintana Roo have adapted and endured, yet perhaps not thrived due to the continually changing and often constricting policy, socioeconomic and biophysical environments. We highlight below several new challenges for CFM on the immediate horizon. In 2013, Mexico introduced its National Strategy for Sustainable Forest Management and Increased Production and Productivity 2013–2018 (ENAIPROS), also considered part of the new National Forest Program 2014–2018. This new initiative seeks to promote the sustainable production of forest resources, setting out to reactivate the forest sector economy, generate employment and improve incomes of communities in forested regions, while simultaneously increasing the provision of environmental services and reducing carbon emissions [130]. ENAIPROS specifically lays down ambitious goals and presents tough challenges for the forest sector including: (1) doubling timber production to 11 million m^3, (2) tripling certification of sustainably managed forests to 2.5 million ha, (3) increasing commercial forest plantations from 242,152 to 384,661 ha by 2018 and (4) creating 25,000 permanent jobs in the forest sector [81]. This recent national strategy offers promising opportunities for CFM countrywide through development and implementation of programs designed to strengthen CFEs via improved organization, commercialization, modernization, and financing. These programs aim for community appropriation of productive processes to increase productivity and forest conservation specifically for the benefit of forest-based communities. In addition, the new strategy sets out to transform forest management through improved silvicultural and management practices that incorporate criteria for biodiversity conservation [81]. To date, 50 projects have been implemented in production forests countrywide, creating 750 community promoters charged with strengthening 750 ejido CFEs through financing, monitoring and evaluation mechanisms [131].

While these promising and ambitious federal national forestry programs intend to promote CFM, over regulation and misaligned agricultural and forest policies are considered a major obstacle to CFE efficiency and productivity in Quintana Roo [67]. Second-tier organizations, forest technicians, and forest beneficiaries complain of excessive paperwork, cumbersome procedures, unrealistic time frames to

complete procedures, and of delays in harvest authorizations [67]. This became evident in the aftermath of hurricanes when conflict and chaos ensued as ejidos attempted to legally harvest fallen wood and deal with forest restoration and emergency needs [126]. The hurricane aftermath also accentuated the heavy costs and bureaucratic burdens of sustainable forest management certification. Currently, the United Nations Development Program (UNDP), Rainforest Alliance, CONAFOR and the Mexico REDD+ Alliance (MREDD+) are conducting activities to increase the number of certified ejidos in the region.

Presently, CFM in Quintana Roo has received increased attention as a means to reduce emissions from deforestation and degradation. Community-based initiatives were particularly highlighted with REDD+ programs in the tropics [4,26,27] to encourage "the 'plus' (behaviors) of conservation, sustainable forest management and enhancement of carbon stocks" [25]. As a REDD+ partner, Mexico's REDD+ National Strategy embraces the benchmark of 0% net carbon loss from deforestation, and seeks an increase in the area covered by forest [131] through ground monitoring and payment systems for forest lands throughout the country (ENAREDD+). In Quintana Roo, communities, second-tier organizations, and consultants are currently engaged with REDD+ programs aimed to integrate CFM and measure and monitor carbon stocks related to forest management activities in the region. Presently, CONAFOR and the MREDD+ program, in conjunction with state-level government institutions and NGOs, are developing mechanisms to implement carbon payments to ejdo communities in the Yucatan Peninsula, a topic that has created much confusion, criticism and debate among forest beneficiaries and other actors involved. This in itself creates a major challenge for the M REDD+ program.

Critical silvicultural and forest production challenges also face CFM in Quintana Roo. Potentially dwindling stocks of valuable timber species are partially attributed to poor regeneration and growth under current management schemes. Selective timber harvest creates mostly small canopy gaps that do not provide the full light conditions required for regeneration of shade intolerant species (e.g., mahogany) [46]. More intensive silviculture has been proposed to create larger canopy gaps from 1/4 to 1 ha, also referred to as "bosquetes" [54,67]. In spite of positive experimental results [50], risk averse institutions, such as SEMARNAT and CONAFOR, and uncertain financial feasibility have dampened adoption of these promising alternative silvicultural practices. From a marketing and commercialization perspective, CFM will continue to face challenges of operating in a free-trade environment with growing competition from planted timber and timber substitutes. The UNDP, Rainforest Alliance and the Southeastern Ejido Alliance are spearheading efforts to provide desperately needed opportunities to strengthen CFE administrative and marketing capabilities. Furthermore, communities are challenged to engage young people in forest enterprises, as they are drawn to an expanding state tourism sector.

Finally, corruption and lack of transparency also present worrisome and major challenges to CFM growth and strengthening. Although present since CFM formalization in the mid-1980s [69], these challenges continue to persist in all institutional levels from community governance to state and federal institutions. For example, grants and subsidies to establish mills for CFE development have often been undermined by petty corruption within ejido ruling members [97]. Several of the authors (E.A.E., D.W.R. and P.N.C.) are cognizant of many cases where ejido presidents have stolen from either buyer loans or government grants and cases of second-tier organizations and technical consultants that mishandled funds or deliberately and wrongfully over-charged communities for their services. In poorer forest communities with little integration into forest management activities, corruption can result in complete discontinuation of forest management activities. For more developed CFEs, ongoing strategies to reduce corruption

include increased enterprise transparency, greater reinvestment of forest revenues into the enterprise, and dispelling the notion that CFEs are safety nets [97].

6. Conclusions

Many forest communities in Quintana Roo have persisted through policy shifts, changing economic trends and major biophysical shocks as described above. While the number of ejidos involved in legal harvest of timber products has fluctuated between 50 and 80 between 1995 and 2013, the reality is that only a handful of these communities (mostly Type III and Type IV) have maintained profitable and functioning CFEs. Most forest communities in the region have survived and adapted by continually shifting timber products being marketed, and by capitalizing on other forest values and opportunities, such as PES (biodiversity and hydrological) and ecotourism activities. Obtaining resources from government programs and maintaining forest management activities through subsidies has been a crucial adaptive strategy for many, albeit not a very sustainable one. With current reductions in SEMARNAT and CONAFOR funding, forest communities in the state may feel the brunt of these budget cuts in the following years. In order to strengthen CFM in Quintana Roo and benefit a wider spectrum of forest communities, several important and current issues need to be addressed and integrated into forestry development and conservation strategies and policies:

(1) Limited market access and very few local buyers who control much of the timber demand and extraction from forest communities (e.g., Type II communities); this has been a major constraint to CFM sustainability in the region, requiring both public and private investment toward strengthening CFEs to manage their own timber extraction and processing operations, as well as improve their business management and marketing capacities. Harvesting and extraction by buyers who bring their own machinery and operators is typically much less planned and can be more damaging to forests than when conducted by the CFE itself. It is important that project strategies and forest development policy contemplate mechanisms to invest in and strengthen CFEs, increasing the number of Type III and IV forest communities, in addition to increasing potential buyers and markets available to community timber producers.

(2) Over-regulation and excessive requirements for forest management from government institutions; this is a very visible and documented constraint to CFM development that frustrates many actors involved both with conservation and forest management in the region [132]. While certain efforts have been applied to reduce the bureaucracy and requirements of forest management authorizations (such as requiring only one integrated management plan as opposed to an additional environmental impact statement), the reality is that trying to comply with different institutions and regulators (e.g., CONAFOR, SEMARNAT, CONABIO, *etc.*) involved in forest management is often a daunting and discouraging task for many communities, limiting their involvement in forest management. Better integration of government institutions and policy alignment is sorely needed in Mexico when it comes to the forest sector. In addition, incentive based systems (rather than penalty-based systems) should be applied, in addition to reducing bureaucratic requirements and costs to those who demonstrate better management practices, such as FSC certification, as well as a history of compliance with government regulations.

(3) Poor governance and organization of many ejidos is perhaps the most difficult and internal challenge to overcome for the communities themselves, and current CFM development projects and initiatives in the region. It is important to integrate more community leadership and conflict management training through CFM development programs and conservation projects as well. While poor governance and corruption occurs at all levels of government, improved community organization and leadership, transparency and democratization are essential to reduce problems of corruption and conflicts arising from it.

(4) Lack of research on the sustainability of forest management practices in the region as well as in the implementation of potential alternative silvicultural systems has been a major bottleneck to the development of CFM in the region. In large part, this may be due to lack of government funding and resources toward increasing forestry and silvicultural research, as well as poorly developed and funded research and extension mechanisms to promote improved management practices. Not surprisingly, government institutions are the most averse and closed to researching and implementing alternative forest management systems and silvicultural practices, such as integrating slash and burn agriculture, intensifying timber harvests through small clear cuts and prescribed burning. Aversions are mostly due to conservation and environmental concerns, public perceptions of forestry, in addition to regulatory constraints.

(5) Finally, integration of biodiversity conservation and reducing carbon emissions into current forest management practices is a trending issue that communities and CFM in Quintana Roo must increasingly face and contemplate when managing their forests. International projects related to the REDD+ initiative are already being implemented for this purpose by organizations such as UNDP and the Nature Conservancy (TNC). These initiatives may present new opportunities to forest communities in Quintana Roo if low cost and effective biodiversity and carbon emission evaluation and monitoring systems are devised, and economic returns from timber production are not negatively impacted by integrating these practices. In that sense, government programs and international projects will need to promote further research and provide adequate funding to for the adoption and implementation of biodiversity conservation and reduced carbon emission practices into CFM in Quintana Roo. Payment systems and/or benefits obtained from improved management practices for carbon emissions reduction as well as biodiversity conservation will need to be sufficiently attractive to forest communities in order to successfully integrate these environmental services into CFM in Quintana Roo.

Clearly, continuity and survival of community forest management in Quintana Roo, in the past and present, has been related to adaptive management and diversification strategies by local communities, forest civil society organizations, and NGOs, all working in the region. The authors of this article finally conclude that strong internal institutions coupled with a well-developed network of partners (e.g. forest technicians, second-tier organizations and NGOs) impart increased robustness and enhanced adaptive capacity of forest communities in Quintana Roo.

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Author Contributions

All the authors participated in the bibliographical review and contributed in writing and editing the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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