COMMUNITY EMPOWERMENT AND SUSTAINABILITY OF THE COMMON FOREST
OF CHERAN, MEXICO

By

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ABSTRACT

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In Mexico, approximately 80% of the forest is commonly owned by local communities and its management is decentralized. Evidence suggests that in many cases, decentralization is ineffective in reaching positive social and environmental outcomes due to a lack of power for local actors. This research aims to investigate how community empowerment impacts the sustainability of common forest. During the 2000´s, the indigenous community of Cheran lost a third of its forest to foreign loggers linked to criminal organizations. Given the lack of response by authorities, in 2011 the community conducted an armed resistance against the intruders and recovered control over their territory. Then, they completed a legal process that ended in the establishment of a traditional self-governance system. I investigated three research questions: 1) What kind of power did the community gain in relation to natural resources management? 2) How have the institutions for the sustainable management of common pool resources (CPRs) evolved after 2011? and 3) How has forest land-cover changed from 2005 to date? To answer the first two research questions, I conducted a qualitative case study. I found that the community in fact gained authority over the management of the forest and improved their institutions to better resemble Ostrom's principles for sustainable management of CPRs. To answer the third research question, I performed a semi-automated land cover change assessment between 2005 and 2020. The area covered with healthy forest reached its lowest point in Cheran in 2014 but has been recovering ever since. This study provides empirical evidence suggesting that community empowerment in decentralized forest management can facilitate the creation of robust forest institutions and reduce deforestation.

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1. INTRODUCTION

Local communities own and manage 80% of the forests in Mexico (Bray et al., 2003). In 1992, the Mexican agrarian law was modified as a consequence of neoliberal policies; communities gained the right of alienation[1] over the land and the forest management was decentralized (De Janvry et al., 2001). According to the literature on decentralization, this policy was meant to promote a more efficient, equitable and sustainable use of natural resources (Ribot, 2002). However, some authors argue that neoliberal corrupt elites oftentimes take power away from local communities to serve their own interests, and fail to provide security and legality (Cortés Calderón, 2018).

In general, the decentralization of forest management in Mexico has failed to deliver positive environmental and social outcomes (Deininger & Minten, 1999; FAO, 2010). Between 1990 and 2000 Mexico lost an average of 354,000 hectares of forest per year, occupying the 7th place worldwide in deforestation for that period (FAO, 2010). In addition, according to the World Bank (2005), more than half of the Mexican population lives under the poverty line and 60% of the poor live in rural areas. Deininger & Minten (1999) found that poverty is associated with higher levels of deforestation in the country.

In some countries, the decentralization process did not include an increase of stakeholders' power to create rules and make decisions over natural resources (Agrawal & Ribot, 1999). Some empirical evidence from Bolivia, Kenya, Mexico, and Uganda suggests that disempowered local actors are less likely to engage in effective collective action after decentralization of natural resource management (Coleman & Fleischman, 2012).

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[1] The right to sell or lease the land (Schlager & Ostrom, 1992)

Empowerment is the process by which people gain power; meaning that they expand the authority and control over the resources and decisions that affect their lives (Narayan, 2007). It is a mainstream concept in the development literature and central to the work of many development organizations; it is recognized as an instrument for community development, poverty alleviation, public health and local governance (Alsop & Heinsohn, 2005; Hennink et al., 2012; Luttrell et al., 2007). In the context of natural resources, empowerment is central for sustainability and refers to the right to access, use and manage resources by individuals or communities (Hennink et al., 2012).

The objective of this research is to use the case of the indigenous community of Cheran, Mexico to study the relationship between community empowerment, resource governance and sustainability of the commons under decentralized management. The forest users' group or *comunidad de* Cheran collectively own 17,000 ha of temperate forest in the State of Michoacán, Mexico. Forest users live in a town called Cheran, which has approximately 18,000 inhabitants and it is the capital of the municipality with the same name. During the second half of the 2000's, illegal logging became a regular practice in Cheran. The situation in the whole country was chaotic and violent as a consequence of the "war on drug cartels" by the federal government. Outsiders linked to criminal organizations took advantage of the situation to rob wood from Cheran, and state authorities failed to stop them. Consequently, the people from Cheran organized an armed resistance against external loggers and recovered control of their territory (Luján-Álvarez et al., 2015; Alejandra Velázquez, 2013). Dissatisfied with the performance of State authorities, the community decided to get legal advice and succeeded to substitute the municipal government with an autonomous form of government recognized by the Federal Government of Mexico (Luján-Álvarez et al., 2015; Alejandra Velázquez, 2013). This form of governance is known as "usos y costumbres" or "uses and costomes"; and it recognizes indigenous communities' rights to elect

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their authorities according to their traditions. This figure is widely used in states such as Oaxaca where most inhabitants are indigenous (Valdiva Dounce, 2010).

The case of Cheran provides the opportunity to assess the relationship between empowerment, governance and environmental sustainability of the commons, in this case the forest. I explored three research questions: 1) What kind of power did the community gain in relation to natural resources management? 2) How have the institutions for the management of common pool resources (CPRs) evolved after 2011? and 3) How has forest land-cover changed from 2005 to date? I applied a mixed methods approach to answer these research questions. Using qualitative research methods, I assessed the process of empowerment and the evolution of forest management institutions to answer question 1 and 2. The quantitative part of this research consisted of a land cover change analysis performed using Google Earth Engine to answer question 3.

I found that the community gained considerable authority over the management of the forest. After 2011, the power to enforce rules, also known as judicial power was completely shifted from the State authorities to the community. The power to create rules was not totally transferred to local authorities, but the community certainly gained influence over the creation of forest institutions. Before 2011, the community already had *de jure* executive power; however, after the mobilization they got *de facto power* for executing the decisions over the forest.

In terms of common forest institutions, the community experienced several changes after 2011. Ostrom's principles for the sustainable management of CPR's can be divided in endogenous and dependent (Ostrom 1990, Agrawal 2001). The first six principles are considered endogenous because they are determined and affected only the user group, while the last two principles depend on the community's interaction with external authorities. In fact, Agrawal (2001) states that "most

of Ostrom's principles focus on local institutions, or on the relationships within the local context. Only two of them, about legal recognition of institutions by higher level authorities and about nested institutions, can be seen to express the relationship of a given group with other groups or authorities" (p. 1652). Endogenous institutions became more robust in Cheran after 2011. On the other hand, the community struggled to gain recognition of their rights to organize and their institutions are not fully nested with higher levels of governance.

In 2005, Cheran had 14,000 hectares of healthy forest. By 2014, that number fell to 11,000 hectares, 3,000 hectares of forest were lost. In 2020, after 9 years of the empowerment of the local community, the surface covered by healthy forest is 13,000 hectares or 92% of the surface they had in 2005.

This thesis has both practical and theoretical contributions which are linked. This research contributes to the literature of the commons, but more importantly to the one on decentralization and how to devolve functions to local communities and that includes the devolution of power. On the other hand, a practical contribution is the fact Cheran can serve as an example on how providing power to communities can improve the governance of the forest. Cheran improved its forest through the design of institutions, this is a crucial lesson for other communities in Mexico considering that the country is struggling with deforestation. The people of Cheran had to go to many difficulties and legal battles to get that right. It is fundamental to make decentralization real and easier for communities.

The rest of this document is organized as follows: Section 2 contains a review of the relevant literature; Section 3 describes the study site in detail; Section 4 explains the research method; section 5 shows the findings of this research and Section 6 is a general discussion.

2. LITERATURE REVIEW

2.1 Common pool resource management

"The tragedy of the commons" (Hardin, 1968) describes the expected degradation of common resources when many users have access to them, because each user seeks to maximize his immediate profit by extracting as many units of the resource as possible. Even though Hardin's article was not supported by empirical evidence, his paper was translated into the claim that only private property or centralized management exerted by the State could avoid the degradation of the commons. Hardin's article was so influential that many countries implemented centralized control and privatization policies, which resulted not only in the dispossession of stakeholders, but in the degradation of resources (Ostrom, 1990).

After Hardin's article, researchers started to investigate case studies from around the globe where local communities had successfully engaged in collective action, resulting in sustainable use of resources (Baland & Platteau, 1996; Ostrom, 1990; Wade, 1988). These studies showed that the tragedy of the commons did not always occur. Furthermore, the studies showed that Hardin's article failed to make the distinction between open access and common property, and that communities can create rules to manage their shared resources. This has led to the misconception that communities could not communally manage their resources in a successful way (Schlager & Ostrom, 1992).

In addition, Ostrom (1990) created the term "common pool resources" (CPR) to refer to any "natural or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use" (Ostrom, 1990:30). CPRs have two characteristics: subtractability and excludability (Ostrom, (1990). Ostrom (1990) analyzed cases of local communities that successfully engaged in collective action

to manage their CPRs in a successful way. She proposed eight design principles that were the shared features of the robust user-organized systems who were developing sustainable CPR management.

Schlager & Ostrom (1992) noted that all regimes that were not private or state property were assumed to be of one single kind, disregarding the difference between "open access" and "common property" regimes, situation that was leading to errors in policy analysis. In addition, they proposed a classification of the property-right regimes that included authorized user, claimant, proprietor and owner. Each of those categories corresponds to a distinctive bundle of the five possible property rights: access, withdrawal, management, exclusion and alienation (Table 1).

Table 1: Bundles of property rights (Adapted from Schlager & Ostrom (1992))

Right	Description	Owner	Proprietor	Claimant	Authorized User
Access	Enter a defined physical property	Yes	Yes	Yes	Yes
Withdrawal	Obtain the products of the resource	Yes	Yes	Yes	Yes
Management	Regulate internal use patterns and transform the resource	Yes	Yes	Yes	No
Exclusion	Determine who will have an access right	Yes	Yes	No	No
Alienation	Sell or lease the above rights	Yes	No	No	No

As Table 1 shows, according to Schlager & Ostrom (Schlager & Ostrom, 1992), owners possess all five property rights; therefore, they have incentives to take long term actions for the conservation of resources. "Authorized users lack of authority to participate in collective action to change operational rules" (p. 252); "[…] authorized users do not design the rules they are expected to follow, they are less likely to agree to the necessity and legitimacy of the rules" (p. 257). This

situation can lead to destruction of the resource unless mechanisms for monitoring and enforcement of rules are set in place (Schlager & Ostrom, 1992).

According to Gibson, McKean, & Ostrom (2000, Chapter 6) there are three fundamental requirements for successful common pool resource management by local people: 1) users must highly value the natural resource, 2) they must have property rights over the resource, and 3) they must be able to create institutions to regulate the use of the resource. These three requirements have been widely studied (Bremner & Lu, 2006; Ensminger, 1997; Anne M. Larson & Soto, 2008; Tucker, 1999; Velez, 2011; Velez et al., 2020). Tucker (1999) found no differences in forest conservation lost in Honduras between two different property rights regimes: common and individual property rights. She attributed the success of common property to the existing institutions historically created by local communities. After reviewing the existing literature, Larsen & Soto (2008) argue that having the right to manage natural resources and excluding outsiders from using them are essential conditions for sustainability. Velez et al (2020) found that formalizing property rights via collective titling in Afro-Colombian communities significantly reduced deforestation when locals were involved in the creation of rules for the use of the resources and also were able to exclude private companies from extracting timber.

Agrawal (2001) classified the characteristics of common property identified by Wade (1988) into four categories: 1) Resource system characteristics, 2) Group characteristics, 3) Institutional arrangements and 4) External environment. Two additional categories contain the relationship between 1 and 2 (Resource system characteristics and Group characteristics) and between 1 and 3 (Resource system characteristics and Institutional arrangements). Figure 1 shows a synthesis of Agrawal's classification.

Figure 1: Facilitating conditions for CPR sustainable management (Agrawal 2001)
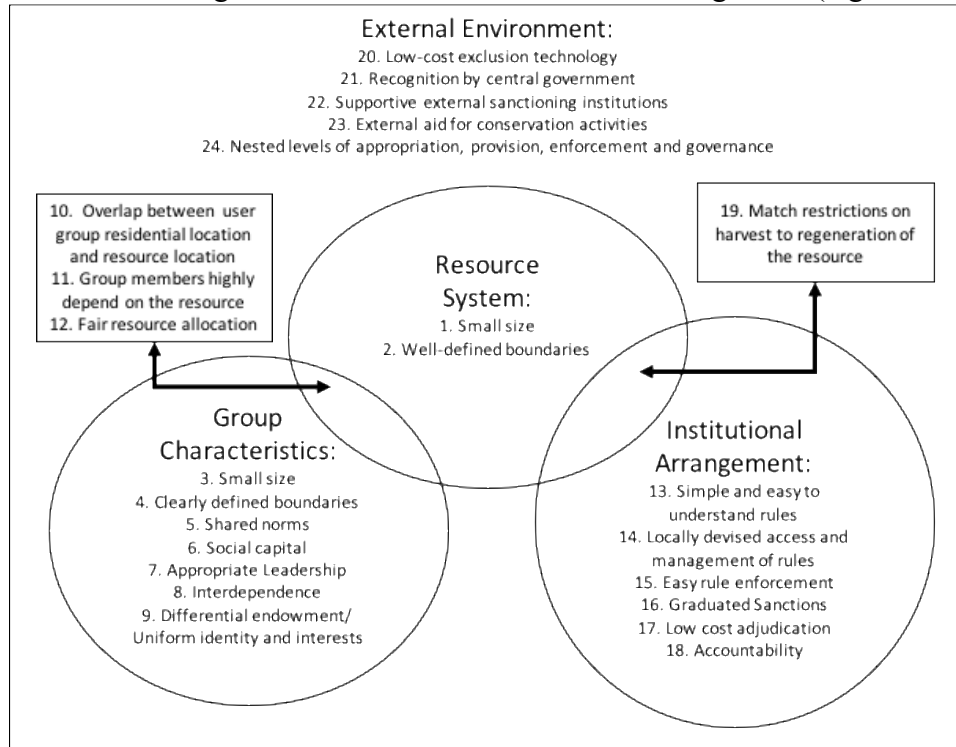
2.2 Ostrom's design principles as an assessment tool for CPR management

Ostrom's design principles help to look at the CPRs governance structures (Coria & Sterner, 2011; Cox, 2014), knowing that the design were supposed to necessary conditions but not sufficient (Ostrom, 1990). The principles have been used as a framework to study resource sustainable management of a big variety of CPR systems at the local (Kamran & Shivakoti, 2013; Sattler et al., 2015; Trimble & Berkes, 2015; Vélez, 2009), national (Lacroix & Richards, 2015; Lancaster et al., 2015; Raudla, 2010; Sarker et al., 2015) and even global level (Johnson-Freese & Weeden, 2012).

Based on the meta-analysis of 91 studies that evaluated Ostrom's design principles, Cox et al (2010) proposed some improvements to Ostrom initial list as shown in Table 2.

Table 2: Modified CPR's design principles (Cox et al (2010)

Principle	Description
1A	**User boundaries:** Clear boundaries between legitimate users and nonusers must be clearly defined.
1B	**Resource boundaries:** Clear boundaries are present that define a resource system and separate it from the larger biophysical environment.
2A	**Congruence with local conditions:** Appropriation and provision rules are congruent with local social and environmental conditions.
2B	**Appropriation and provision:** The benefits obtained by users from a common-pool resource (CPR), as determined by appropriation rules, are proportional to the amount of inputs required in the form of labor, material, or money, as determined by provision rules.
3	**Collective-choice arrangements:** Most individuals affected by the operational rules can participate in modifying the operational rules.
4A	**Monitoring users:** Monitors who are accountable to the users monitor the appropriation and provision levels of the users.
4B	**Monitoring the resource:** Monitors who are accountable to the users monitor the condition of the resource.
5	**Graduated sanctions:** Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and the context of the offense) by other appropriators, by officials accountable to the appropriators, or by both.
6	**Conflict-resolution mechanisms:** Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.
7	**Minimal recognition of rights to organize:** The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.
8	**Nested enterprises:** Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

In the case of forest, Johnson & Nelson (2004) used the design principles to document forest status after severe fires in a national park in Mexico and analyzed the existing common forest institutions. According to the authors, "each of the design principles seems necessary for the functioning of the common property and provides insights regarding the outcome of management" (Johnson & Nelson, 2004, p. 728).

Gautam & Shivakoti (2005) assessed forest governance systems in Nepal using the design principles; the authors found that of the two case studies they did, the forest with relatively good conditions was the one with institutions that better resembled Ostrom's design principles. Van Ast, Widaryati, & Bal (2014) found that in the 'Herman Yohannes Grand Forest Park' in Indonesia, most of the design principles were present in the functioning of its traditional institutions. Moreover, the authors suggested that the presence of those design principles contributed to the sustainability of the forests over centuries (van Ast et al., 2014, p. 302).

2.3 Forest commons in Mexico

The Mexican Revolution (1910-1917) was led by peasants whose main demand was land redistribution because most of the land in the country was owned by few very rich families, while most of the population was landless and poor. As a result, the current Constitution of Mexico (1917) recognizes three types of rural property: national lands, private property, and the agrarian reform sector or *ejido* sector. The Mexican Constitution granted long-term and stable usufruct rights over the land to the peasants; however, ultimate ownership was granted to the State, which means that stakeholders did not have the alienation right. By excluding this right, the State retained great control over the decision-making in the communities; a situation that De Janvry et al. (2001) called State-led governance. Between 1920 and 1940, president Cardenas led the agrarian reform that transferred half of the Mexican territory's (105 million hectares) tenure into local communities (both ejidos and communities) (Barnes, 2009; Bray et al., 2003).

In 1992, Article 27 was modified to promote community-led management. The new legislation allows privatization of individual plots, association with private interests outside the *ejido* and the use of land as collateral for credit. More importantly, decision-making was

decentralized, giving communities full control over the land. In that sense, *ejido* sector proprietors became common owners after that amendment to agrarian law (De Janvry et al., 2001).

The same year, the forestry policy was also modified to match the Article 27 amendment and the liberalization of the market enforced by the North American Free Trade Agreement (NAFTA). Forestry activities were deregulated allowing *ejido* communities to establish commercial plantations in partnership with private enterprises. The reform was meant to integrate forestry communities to the global market. However, federal policies were poorly designed and lacked incentives for conservation that resulted in deterioration of local institutions, impoverishment of the communities and forest degradation characterized by clandestine logging (Pérez, 2003).

Between 1990 and 2000 Mexico lost an average of 354,000 hectares of forest per year, occupying the 7th place worldwide for deforestation for that period (FAO, 2010). Most of the deforestation happens in the South of the country where biodiversity is greater (A. Velázquez et al., 2002). Estimates range widely, but the consensus is that deforestation rates have been declining since 2000 (Kolb & Galicia, 2012). Still, Bradshaw, Giam, & Sodhi (2010) ranked Mexico in 9th place for natural forest lost in 2010.

Deininger & Minten (1999) investigated the contribution of different socioeconomic and geographic factors to deforestation in Mexico using land use data and its changes; they did not find differences between common and private property. They also concluded that provision of technical assistance decreases deforestation, while poverty is associated with higher levels of deforestation.

According to the World Bank (2001), the *ejido* represents an opportunity for the implementation of poverty alleviation and forest conservation strategies because a large proportion

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of the forest is owned by poor communities. However, the same report mentions that forest policy provides minimal support to communal forest owners, and add that forest policy focuses on control rather than incentives which makes compliance difficult and expensive (World Bank, 2001). The excessive regulatory burden of forestry makes it less attractive than agriculture for land owners which is an incentive for them to clear the forest for crops (World Bank, 2001). Still, the most functional and productive *ejidos* in Mexico are those that focus on forestry rather than agriculture (Barnes, 2009). According to (Barsimantov et al., 2010) even though the reform of 1992 enabled owners to transition to private property, communities whose main activity was forestry have been less likely to change from communal to individual property possibly because forest can be managed more effectively as a whole; other factors that relate to the permanence of common property are strong governance and ethnic homogeneity.

Despite the loss of forested area in the country as a whole, Mexico has some remarkable cases of sustainable community-based forestry (Bray et al., 2003, 2005; Merino & Cendejas, 2017; Orozco-Quintero & Davidson-Hunt, 2010; Pérez, 2003; Tucker, 2004). Under appropriate institutional conditions and thanks to their high levels of social capital, forestry communities have shown significant capacity to deliver positive social, economic and ecological outcomes. Orozco-Quintero & Davidson-Hunt (2010) study a well-known example of such forestry communities is San Juan Nuevo in the Purepecha region of the State of Michoacán. The authors found enough empirical evidence to support the community's capacity to maintain its resources while achieving a positive socioeconomic impact through forestry communal enterprise; all of this, thanks to very robust institutions.

2.4 Decentralization, empowerment and natural resource governance

Decentralization is the devolution by central government of specific functions to regional and local agents that are independent of the center (Faguet, 2014) The theoretical arguments in favor of decentralization include its potential for increasing accountability, citizen voice and governance as well as limiting abuses of power by central authorities (Faguet, 2014). Many countries have decentralized forest management and the effects of such reforms have been studied widely; according to the empirical evidence, decentralization's social and environmental outcomes differ from country to country (Larson & Soto, 2008; Ribot, 2002; Ribot et al., 2006; Wright et al., 2016). For example, Wright et al. (2016) studied decentralized forest management in Peru and Bolivia, and found that decentralized management can reduce deforestation but only when forest user groups are actively engaged in governance, and have meaningful roles in decision-making, monitoring and conflict resolution.

Larson & Soto (2008) argue that the results of decentralization are generally disappointing because the polices have been poorly implemented as they rarely change the power relations in natural resources management. In the same line of argument, Larson et al (2010) found that decentralization polices enacted around the world have legally transferred property rights to forest user groups, but in practice the transference of power has been limited by regulations, competing claims and State actors seeking for the retention of control.

According to Coleman & Fleischman (2012), the ecological and socioeconomic outcomes of local collective action for the management of the commons in a decentralized environment are a function of empowerment and accountability. Decentralization initiatives that include strong accountability and local empowerment are more likely to achieve their stated policy goals: resources sustainability and improving rural livelihoods (Coleman & Fleischman, 2012).

Narayan (2007) defines empowerment as the expansion of assets and capabilities of vulnerable groups; such expansion results in people's increased power to control their lives. According to Cornwall (2008), empowerment is a continuing, dynamic and transformative form of participation where people are able to decide and act by themselves; citizen control or citizen power is the highest level of participation. Both definitions consider that empowerment is a process whose outcome is an increased control over someone's own life.

In the context of natural resources, empowerment refers to the ability of individuals or communities to access, use, and manage natural resources towards sustainability (Hennink et al., 2012). Coleman & Fleischman (2012) define empowerment in that context as the transfer of authority from central government to local actors so that they can make decisions over their resources. Theoretical and empirical evidence suggests that sustainable decentralized management of the commons necessarily requires effective empowerment in all its instances to local representative authorities (Agrawal & Gibson, 1999; Anne M. Larson & Soto, 2008; Ribot, 2002; Wright et al., 2016).

Agrawal and Ribot (1999) distinguish three types of power involved in the decentralized management of CPR: 1) the power to create and modify rules or legislative power, 2) the power to make decisions about the usage of resources or executive power, and 3) the power to implement and ensure compliance of the rules and adjudicate disputes or judicial power.

2.5 Land cover change assessment using Google Earth Engine

Google Earth Engine (GEE) is a free-access potent tool for the investigation of land cover changes (Nyland et al., 2018). GEE is not only a repository of satellite imagery and geospatial datasets but also a cloud-based geospatial processing platform that utilizes a Javascript or Python

Application Programming Interface (API) which makes its use very efficient for users with varying computing resources (*Google Earth Engine*, 2020).

Landsat imagery

For the las 4 decades, NASA's Landsat program has continuously provided optical satellite imagery of the earth´s surface thanks to the series of 8 satellites launched between 1972 and 2003. Landsat imagery is cataloged using the Worldwide Reference System (WRS) which assigns sequential Path numbers (from east to west) to the 251 satellite tracks. As the satellite moves along the path, a raw number is assigned to the latitudinal center line of a frame. Paths and Rows form a matrix where each image can be identified by this notation (*The Worldwide Reference System. Landsat Science*, n.d.)

This study utilizes data acquired by Landsat 7 from 2005 to 2020. Landsat 7 was launched in 1999 and is equipped with an earth-observing instrument called the Enhanced Thematic Mapper Plus (ETM+) which incorporates hardware and processing improvements over its predecessors, as well as improvements in spatial resolution in the thermal bands. In 2008 the Landsat archive of imagery became free to the public (*The Worldwide Reference System. Landsat Science*, n.d.). Table 3 shows the band designation for the ETM+ instrument on board Landsat 7.

Table 3: Band designation of Landsat 7 (NASA, 2019)

Band	Wavelength (micrometers)	Resolution (meters)
Band 1	0.45-0.52	30
Band 2	0.52-0.60	30
Band 3	0.63-0.69	30
Band 4	0.77-0.90	30
Band 5	1.55-1.75	30
Band 6	10.40-12.50	60 (30)
Band 7	2.09-2.35	30
Band 8	.52-.90	15

Normalized Difference Vegetation Index (NDVI)

   The Normalized Difference Vegetation Index (NDVI) is an indicator of the presence of healthy vegetation within a pixel of a satellite image, it is calculated using the values for visible and near-infrared light in each pixel using this formula: NDVI= (NIR – Red)/(NIR + Red). Healthy vegetation absorbs most of the visible light that hits it and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. NDVI ranges from -1 to 1; healthy vegetation presents NDVI values higher than .6 while grassland usually has low values. Negative NDVI values correspond to bare soil (Herring, 2000).

Figure 2: NDVI temporal spectra for land cover classes of interest (Knight et al., 2007)
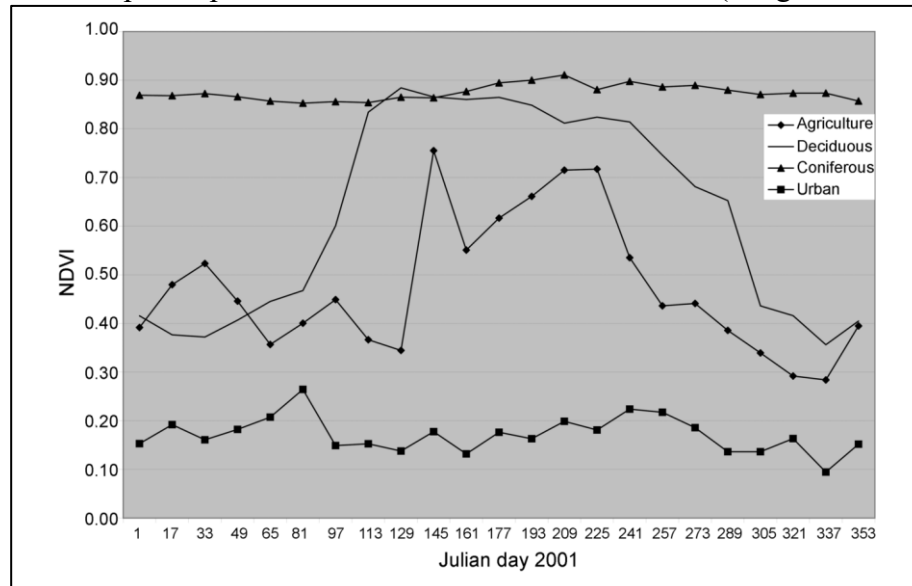
   As shown in figure 2, the NDVI values of coniferous are constant throughout the year whereas the NDVI values of agriculture land and deciduous vegetation drastically drop during the dry season. The difference in NDVI values during the dry season (October-march) among classes make it easy for classification algorithms to differentiate them.

Random Forest classification

Random Forest is a machine learning classification method that constructs a multitude of decision trees at the time of model training and produces the class that is the of the classes of the individual trees (*Decision Tree Learning*, n.d.). Random decision forests corrects for decision trees' habit of overfitting to their training set (Breiman, 2001).

When used in for the classification of imagery, the random forest builds an array of classification and regression-tree classifiers that use bootstrapping of pixels contained in training polygons for each land cover class. The class for each pixel is determined via a voting process of the trees where the most popular class at each node is selected (Nyland et al., 2018).

An accuracy report of a random forest classification usually includes a confusion matrix, estimates of overall accuracy, kappa coefficient, user accuracy, and producer accuracy for each land cover class. A confusion matrix is a table containing the actual classes in each column while rows contain the number of pixels predicted by the algorithm for each class (Foody, 2002). Table 4 is an example of a confusion matrix. In addition to regular accuracy indicators (Overall, users and producer accuracy) the kappa coefficient is often included because it compensates for chance random agreement. Equations 1-3 define how the accuracy parameters are calculated as described by Foody (2002).

Table 4: Confusion matrix example

Predicted class	Actual class				
	A	B	C	D	Σ
A	n_{AA}	n_{AA}	n_{AA}	n_{AA}	n_{A+}
B	n_{BA}	n_{AA}	n_{AA}	n_{AA}	n_{A+}
C	n_{CA}	n_{AA}	n_{AA}	n_{AA}	n_{A+}
D	n_{DA}	n_{AA}	n_{AA}	n_{AA}	n_{A+}
Σ	n_{+A}	n_{+A}	n_{+A}	n_{+A}	n

$$\textbf{\textit{Equation 1}} \quad \textit{User's accuracy} = \frac{n_{ii}}{n_{i+}}$$

$$\textbf{\textit{Equation 2}} \quad \textit{Producer's accuracy} = \frac{n_{ii}}{n_{+i}}$$

$$\textbf{\textit{Equation 3}} \quad \textit{Kappa coefficient} = \frac{n \sum_{k=1}^{q} n_{kk} - \sum_{k=1}^{q} n_{k+} n_{+k}}{n^2 - \sum_{k=1}^{q} n_{k+} n_{+k}}$$

3. SITE DESCRIPTION: THE COMMUNITY OF CHERAN, MICHOACÁN

Cheran is one of the 11 municipalities within the Purepecha region of the State of Michoacán, Mexico. The total area of the municipality is 222.80 km^2 and its population is 12,000. It is in a tropical area with an altitude of 7,874 feet above sea level, where conifer forest is the dominant vegetation type[2]. The surface of Cheran municipality is 24,000 ha and 83% of the total surface of the Cheran municipality is commonly owned by 600 indigenous people (Rojas, 2012). "San Francisco Cheran" is the main town in the municipality of Cheran, which in 2010 had a total population of around 18,000 inhabitants, mostly Purepecha[3] indigenous people. Figure 3 shows the location of Cheran.

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[2] http://www.inafed.gob.mx/work/enciclopedia/EMM16michoacan/municipios/16024a.html
[3] Purepecha is the 13th biggest indigenous group in Mexico with a population of around 200,000 people.

Figure 3: Location of the study site

Michoacan

Región Económica
Meseta P'urhépecha

During the Spanish colonial period in Mexico (1521–1810), original communities of the Purepecha region received common property titles over this land. After Mexican independence (1810), mestizo communities started to gain recognition as municipalities. Cheran municipality was established in 1868. During President Diaz administration (1876–1910) the original territory of Cheran was in great part divided and transferred to private property; US owned companies initiated the industrialized extraction of wood thanks to the assistance of local authorities and the purchase and rental of extensive areas, situation that caused concentration of land (Rojas, 2012).

Through the Mexican revolution, Cheran went through a turbulent period as did the rest of the country, but the indigenous governance structures survived. During President Cardenas administration (1934-1940) the agrarian reform was extensively applied, distributing land among the peasants with no land and creating the *ejido* sector. In Cheran, the agrarian reform was not

welcomed because it implied greater control by the State. Local groups in favor of the agrarian reform, common land indigenous original owners and private owners continued to dispute the control of the land until 1984 when the federal government solved the disputes establishing well-defined limits between the different kinds of property. About 80% of the land was defined as common property and the rest was individually owned. That arrangement persists until today with one exception already mentioned, in 1992 the common property regime was given the right of alienation (Rojas, 2012).

According to Pérez (2003), forestry activities in the region were more or less successful thanks to the support of the State until the 90s when neoliberal policies destroyed the local governance institutions, cut the public investment and opened the markets to international trade. This institutional reconfiguration caused a crisis of forest degradation and impoverishment in the communities (Pérez, 2003). In this context of failed neoliberal policies, a sector of the population of Cheran mobilized against the ruling party "Partido Revolucionario Institucional" (Revolutionary Institutional Party or PRI) demanding better live conditions and the recognition of their traditional indigenous authorities. However, the movement was eventually incorporated to the "Partido de la Revolución Democrática" (Party of the Democratic Revolution or PRD), the leading leftist party in Mexico at the time which diluted its purpose and power (Nelson, 2003).

During the last 30 years, the violence in Mexico has risen to levels that resemble that of war zones, forcing local communities like Cheran to organize and take control of their own safety (Merino & Cendejas, 2017). In order to understand the context in which Cheran´s mobilization came about, it is crucial to know the evolution of violence in Mexico., the product of a failed war on crime. Table 5 presents a summary of the history of violence related to organized crime in Mexico according to Merino and Cendejas (2017).

Table 5: The evolution of violence in Mexico (Adapted from Merino & Cendejas, 2017)

Period	Highlights
1940′s	• In response to the increasing demand in North America, Mexico started producing poppy and marijuana in large-scale • Drug dealing was mostly tolerated by the local government
1980′s	• Mexico became the main area of transit of drugs coming from South America and Asia to the US • The economic and social influence of the drug cartels increased
1990′s	• The US government promoted direct intervention of the army and local paramilitary groups in the battle against drugs in Latin America. • Anti-drug policies led to the professionalization of drug cartels in the form of greater military power and resources to corrupt authorities.
2000′s	• The power of the Mexican drug cartels increased even more after the dismantling of the Colombian drug cartels.
2000-2006	• President Fox modified the anti-drug strategy of the country and for the first time directly confronted the drug cartels.
2006-2012	• President Calderon toughened action against drug cartels by deploying a large fraction of the national army into the streets. • In response to the increased pressure, criminal groups diversified their activities attacking the populations and seeking control of the local governments. • The number of murders increased by %240 in relation to previous federal government, more than 50,000 people were killed. • Mexico was ranked among the countries with the worst Global Peace Index • In response to the failure of the State to provide security, several social movements and organizations emerged to self-secure their territories.
2012- 2018	• President Peña maintained the war against drugs and formally instituted the army as the provider of security. • The repression of the press grew stronger • Social protest was criminalized • An estimated 450,000 people were directly employed by criminal organizations

When the administration of President Calderon (2006-2012) started a "war" against the drug cartels of Mexico, a crisis of crime and violence took over the state of Michoacán. Taking advantage of the chaotic situation, criminal groups stole wood from community forest on a regular

basis in Cheran. Around 3,000 hectares of its forest was lost to the illegal loggers (España-Boquera & Campo-Jiménez, 2016). Despite multiple complaints by the forest users group, local authorities were unable or unwilling to stop the illegal logging (Rojas, 2012; Ventura Patiño, 2012; Wainer, 2016)

The community started an armed resistance against the illegal loggers and an emancipation process in 2011. In April of that year, a small group of women stopped some trucks that carried illegally obtained wood from their forest. This event triggered a series of struggles between the community and loggers. The mobilization of the community increased during the next days until a general assembly decided to disavow the municipal government. That same year, Cheran refused to participate in the State elections, arguing that the regional government never listened to their demands to stop illegal logging and violence. After a complicated legal process, Cheran achieved electoral independence and currently they are self-governed under a traditional scheme (Rojas, 2012; Alejandra Velázquez, 2013; Ventura Patiño, 2012).

4. METHODS

For this study, I followed a qualitative case-study approach in Cheran. A case study approach is widespread in social sciences including policy science and community studies where the researchers have little control over the circumstances of the object of study, for example in the study of real-life phenomena (Yin, 2009). The case of Cheran is particularly important because in a relatively short period, the community went through a radical change in its governance structures, and those impacted the forest. The selection of methods in this case study aims to gather information that help me understand what was happening with the community and in particular what institutions they created to govern the forest with the power they gained in 2011, and how those institutions were reflected in the ecological sustainability of the forest.

After several years of lawlessness, the community organized and mobilized to stop criminal organizations form robbing their forest. Furthermore, the citizens of Cheran undertook a process that ended in the establishment of a traditional form of government, with considerable independence from the State. The gain in power by the people of Cheran was drastic and closely related to the defense of the commonly owned forest, thus, the case study approach gives me a unique opportunity to study the relationship between community empowerment and sustainability of the commons. Not surprisingly, case studies are prominent in the common forest literature (Gautam & Shivakoti, 2005; Klooster, 1998; Tucker, 2004; Velez et al., 2020), however many of the case studies only report social and institutional data, not often do they also include land cover assessment.

As mentioned earlier, I aim to answer three research questions: 1) What kind of power did the community gain in relation to natural resources management? 2) How have the institutions for the sustainable management of common pool resources (CPRs) evolved after 2011? and 3) How has forest land-cover changed from 2005 to date? In order to answer questions one and two, I conducted in-depth interviews, focus groups and participant observation and analyzed the collected data using the qualitative methods of case studies as described by Yin (2009). Question three was answered using Google Earth Engine to run a semiautomated land cover change assessment from 2005 to 2020. The mixed methods approach allows me to determine the effectiveness of the community's forest institutions with forest land cover as the main output of effective forest governance.

The methods section is organized as follows, I will first describe the methods for data collection and data analysis to answer questions 1 and 2, and then I will proceed to explain the methods to answer question 3.

4.1 Qualitative methods.

I assess empowerment as the change in authority over forest management. The literature acknowledges three kinds of power (Agrawal and Ribot, (1999): a) the power to create rules or legislative power, b) the power to make decisions or executive power and c) the power to enforce rules or judicial power. To facilitate the assessment of power change, I used this division in the collection and analysis of information. In reality, those powers overlap and change from country to country but the division still offers a solid analysis framework. For each of the three types of power, I collected information through interviews done with forest authorities and forest users about who exerted the authority and how, both before and after the establishment of the autonomous government in 2011. This allowed me to determine to what extent the community gained influence over the decisions, laws, regulations and rule enforcement in relation to their forest. The interviews also allowed me to collect information about the origins of the deforestation crisis and the mobilization to complement the existing literature and better understand the context of the empowerment process.

In order to assess forest governance, I looked at the development of institutions using Ostrom's design principles as a framework. I collected information about the compliance of each principle before and after the process of empowerment.

Data collection

Before arriving to the community of Cheran, I contacted the President of the Common Goods, the executive body of the forest users group, Mr. Angel Chapina and we agreed on the terms of my visit and research. When I arrived to Cheran, I was granted written permission by Mr. Chapina to do interviews and collect data in the forest. Written permission is essential because locals mistrust outsiders and the forest rangers continuously survey the forest looking for illegal

loggers. In order to protect the identity of the informants, I gave all of them an Alias that I use in this document.

All the field work was conducted during the months of June and July 2016. I stayed in a cabin that the community built for visitors. This was fundamental for the success of my data collection because it allowed me to become familiar with the different dynamics of the community. I conducted semi-structured interviews and focus groups involving key informants: forest users, local authorities, employees from the community's enterprises and State authorities. The key informants were selected according to their area of expertise and experience. Data collection consisted of a total of 25 interviews, 3 focus groups and participant observation were conducted on key activities like resin extraction and collection, forest surveillance by the rangers and meetings of the forest authorities. Table 6 presents the number of interviews and focus groups done by type of key informant. All the forest users and the community enterprises' employees I interviewed were men, because traditionally they perform the field work. However, the forest, municipality, and state authorities I interviewed included a similar amount of men and women.

Table 6: Qualitative data collection technique

Key informants	Interviews	Focus Groups
Local forest authorities	9	2
Municipal authorities	4	1
Community enterprises' employees	4	0
Forest users	6	0
State authorities	2	0
Total	25	3

Semi-structure interviews

For the study, I conducted 25 interviews with 5 different types of informants: local forest authorities, municipal authorities, community enterprises' employees, forest users and state

authorities. The interviews were semi-structured in nature, which means that few questions were prepared in advance depending of the experience of the informant and his area of expertise; however, the conversation could flow freely.

All the interviewees were purposefully selected. Thanks to the interaction with Mr. Chapina, he introduced me to other local authorities and forest users. This introduction was necessary to gain the trust of the respondents. Then, I took a snowball sampling approach to interview people, which means that I identified additional subjects relevant to the investigation during the interviews and participant observations. I took notes in all interviews and got audio recordings when people gave me authorization to do so. In total, I audio recorded 6 interviews of 25. After the interviews, I reviewed and extended my notes. The interviews lasted between 1-2 hours.

Focus groups

I conducted two focus groups with local authorities, with four and five people respectably. I choose focus groups because the local authorities met regularly and they gave me to join these meetings to talk to them as a group. I took notes and recorded audio with participants' authorization. During the focus groups we talked about empowerment and Ostrom's design principles in a semi-structured way, which means that I guided the participants with questions but for the most part the conversation flowed freely.

Participant observations

I conducted participant observations of different activities associated with the forest. With authorization of the different participants, I took pictures, audio recorded the observation and took notes. The activities were:

- Collection of fallen wood
- Processing of wood

- Preparation of trees to produce resin
- Collection of resin
- Processing of resin
- Forest users meeting determine reforestation strategies
- Fence repairs
- Rangers patrolling
- Supervision of newly reforested areas
- Activists for the defense of the forest meeting
- Administrative tasks in the Council of Common Goods office
- Collection of edible herbs and mushrooms in the forest

Data condensation and data analysis.

I documented interviews without audio recordings and observations using field notes. For all the other interviews, the transcriptions were complemented with expanded notes. All that constituted the raw information for the qualitative analysis. All the information was collected and analyzed in Spanish. I later translated the most relevant parts and some quotes to English for their inclusion in this document.

I analyzed the qualitative information using the iterative and continuous system proposed by Miles, Huberman and Saldaña (2014). First, I developed a coding book (see appendix A) that contained labels, definitions, rules, and examples for the classification of information. The coding book was created based on the literature of empowerment, and Ostrom's design principles. I classified the information about empowerment under the themes: legislative power, executive power, and judicial power. For the data about forest management institutions, I used each of Ostrom's design principles as a theme. In addition, the coding book also contains some topics that emerged during the interviews such as the mobilization of 2011. Once I had a first draft of the coding book, I used it on several interviews, and I modified it accordingly. Then, two researchers external but Spanish native speakers applied the coding book to a sample of interviews to verify its consistency. After that process, the coding book was modified and finalized. Then, I proceeded

to code all transcripts. As I was reading the transcripts, I also highlighted other information I considered important, but that did not fall into any of the preconceived themes of the coding book. Then, I transferred all the information under the same code into a single document, and I summarized the memos individually. Finally, I organized all the summaries in a matrix containing two horizontal cells for each theme that corresponded to the situation before and after the mobilization of 2011 in Cheran.

4.2 Land cover change assessment

In order to assess land cover change in the forest of Cheran, I assembled a Time Series of classified Land Sat 7 image composites covering the years 2005 to 2020 in 3-year intervals. I used images located in Path 28 and Row 46 of the Landsat grid as they contain Cheran forest's footprint. Being a mountainous and rainy area, imagery from Cheran is often obstructed by clouds; therefore, I used images obtained during the dry season (October-March). The classifications can be performed effectively with this imagery because healthy evergreen forest maintains a high NDVI value throughout the year while the values for grassland and agriculture land drop during the dry season making it easier to differentiate classes.

I used GEE to perform supervised classifications of Landsat 7 Tier 1 top of the atmosphere Reflectance (TOA) imagery composites. The TOA product is preferred over the TOA radiance because it contains a quality mask which provides information on a per pixel basis that describes what is contained in the pixel (e.g. cloud, cloud shadow, snow, ice, etc). The GEE algorithm creates a cloud-free stack with all the Landsat 7 available imagery for the months January-March of the studied year. I performed the analysis in three-year intervals to omit short term land cover changes caused by factors different from forest governance such as rain level. A particularly rainy year for example, can show a higher forest land cover than a dry one. The resulting time series consists of

6 3-month composites. Table 7 shows the images GEE used to create the composites of each year of the study. A total of 30 Landsat 7 images were used for the analysis.

Table 7: Landsat Imagery

Year (Number of Images)	Stacked Images	Acquisition Date	Satellite	Path	Row
2005 (4)	LE07_028046_20050112	2005-01-12	L7	028	046
	LE07_028046_20050128	2005-01-28	L7	028	046
	LE07_028046_20050213	2005-02-13	L7	028	046
	LE07_028046_20050317	2005-03-17	L7	028	046
2008 (6)	LE07_028046_20080105	2008-01-05	L7	028	046
	LE07_028046_20080121	2008-01-21	L7	028	046
	LE07_028046_20080206	2008-02-06	L7	028	046
	LE07_028046_20080222	2008-02-22	L7	028	046
	LE07_028046_20080309	2008-03-09	L7	028	046
	LE07_028046_20080105	2008-01-05	L7	028	046
2011 (4)	LE07_028046_20110113	2011-01-13	L7	028	046
	LE07_028046_20110214	2011-02-14	L7	028	046
	LE07_028046_20110302	2011-03-02	L7	028	046
	LE07_028046_20110318	2011-03-18	L7	028	046
2014 (5)	LE07_028046_20140105	2014-01-05	L7	028	046
	LE07_028046_20140121	2014-01-21	L7	028	046
	LE07_028046_20140206	2014-02-06	L7	028	046
	LE07_028046_20140222	2014-02-22	L7	028	046
	LE07_028046_20140326	2014-03-26	L7	028	046
2017 (5)	LE07_028046_20170113	2017-01-13	L7	028	046
	LE07_028046_20170129	2017-01-29	L7	028	046
	LE07_028046_20170214	2017-02-14	L7	028	046
	LE07_028046_20170302	2017-03-02	L7	028	046
	LE07_028046_20170318	2017-03-18	L7	028	046
2020 (6)	LE07_028046_20200106	2020-01-06	L7	028	046
	LE07_028046_20200122	2020-01-22	L7	028	046
	LE07_028046_20200207	2020-02-07	L7	028	046
	LE07_028046_20200223	2020-02-23	L7	028	046
	LE07_028046_20200310	2020-03-10	L7	028	046
	LE07_028046_20200326	2020-03-26	L7	028	046

The three-month image composites were created by flattening the reflectance and NDVI values of the image collections. The median reflectance value for all the optical bands for each pixel was extracted and the maximum NDVI value was appended to the reflectance composite as a band. The resulting image contains the median reflectance and the maximum NDVI value for

each pixel for a three-month period. This arrangement provides extended information for the classification of the images.

Agriculture land is subjected to sudden changes in vegetation depending on human activity and environmental factors such as rain. For example, during an unusually rainy year, farmers can plant short cycle crops to utilize remaining moisture in the soil; the resulting healthy vegetation has high NDVI values and can be erroneously classified as healthy forest by the algorithm. Therefore, the composites of Landsat Imagery were clipped to exclude the agriculture land and the urban area of Cheran which reduced noise. Then the clipped composites were classified using the random forest classification method within GEE. This method requires training polygons for each class; in this case the classes were: 1) Bare soil, 2) Transition forest and c) Healthy forest. I performed some tests where the class Grassland was included but it was difficult for the algorithm to distinguish bare soil from grassland during the dry season because when grassland has low NDVI values. The algorithm also requires validation polygons for each class for the calculation of accuracy parameters. The training and validation polygons were drawn using Google Earth´s high definition imagery archive to find areas whose class remained constant throughout the duration of the study. Figure 4 shows the study area with the polygon that the community claims, the excluded agriculture land and urban area, and the class polygons.

Figure 4: Study area and training polygons
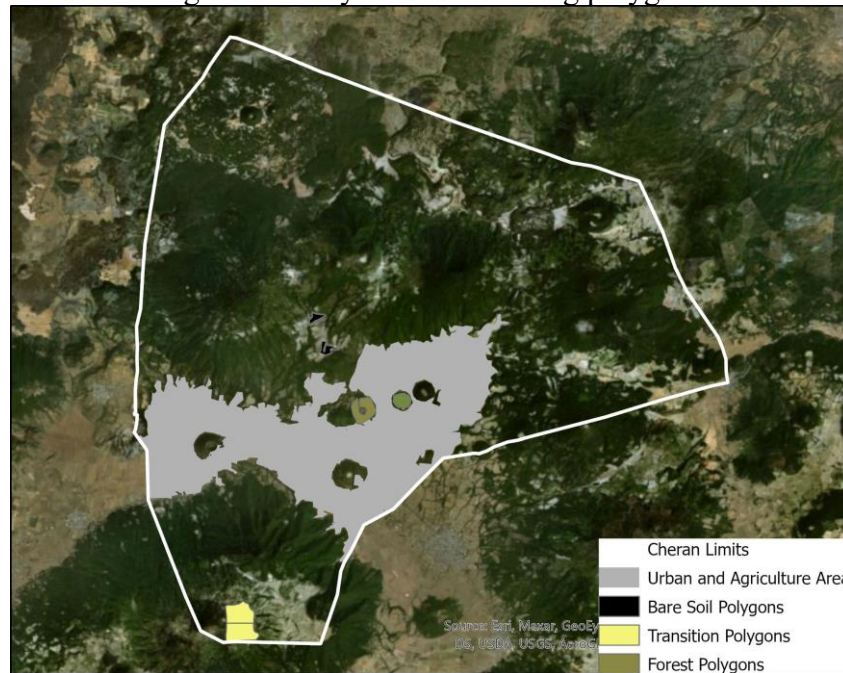
The algorithm reports accuracy via a confusion matrix containing the classification of the pixels within each validation polygon. Ideally, 100% of the pixels inside a validation polygon should fall into the polygons class. The overall accuracy is given by the kappa coefficient which is calculated as described by Foody (2002). The GEE algorithm was also programed to export the classified image and display the area of each class area in square kilometers. The algorithm was applied 6 times with a three-year gap between each measurement and the outputs were recorded to assemble a Timeline Series.

5. RESULTS

This section is organized as follows: first, I will present the results on the origins of the crisis and the mobilization in Cheran in order to provide context to the following sections; second, I will explain to what extent the community won authority over the forest resources. Then I will

explain how the management institutions changed after 2011, and finally, I will address the change in forest land cover.

5.1 Origins of the crisis and mobilization

In the state of Michoacán commercial avocado plantations are historically very profitable; and most of the production is sent to the international markets. Therefore, landowners have monetary incentives for the establishment of avocado plantations. As a result, large areas of forest were converted into avocado plantations, however, Cheran did not follow that trend. Avocado plants are banned from the community since 2011. As the forested area has decreased in the State the supply of timber has shrunk, and buyers have incentives to buy wood in unconventional places like Cheran that was never a commercial producer of timber.

In Cheran, historically, resin has been the most important commercial forest product; however, people also extracted timber to make furniture. The claimants were responsible for managing wood extraction within their assigned land. For the most part, only sick or old trees that did not produce enough resin were cut for timber. In the community, there is a commonly owned processing plant, and several carpentry shops, together they covered the timber supply of the community.

Given the increased demand for timber in the mid-2000s, external loggers started buying trees in Cheran even though the Environment and Natural Resources Bureau (SEMARNAT by its Spanish acronym) did not officially allow the commercial extraction of wood. SEMARNAT is the nationwide branch of the government that is in charge of regulating forests use. The executive body of the forest user group of Cheran called the Council of Common Goods (CBC by its Spanish acronym) and the Municipal Government allowed the commercial extraction of timber.

Furthermore, according to some Cheran inhabitants, the municipal government benefited politically and commercially from that illegal logging as described below:

"The last [Municipal] administration was very involved, they managed the government very badly, they let the loggers grow and they used intimidation to do whatever they wanted" Mr. Jaime

During this same period, the Federal Government undertook a "war" on the drug cartels that destabilized the whole country as the cartels started fighting one another for the control of the territories. In the state of Michoacán, the police forces where overwhelmed by the criminal organizations. The violence and corruption permeated all sectors of society and the drug cartels diversified their criminal activities to include kidnaping, extortion and, illegal logging. The groups that initially purchased wood illegally in Cheran colluded with criminal organizations and started stealing and cutting trees.

"The loggers from outside [the community} came because people from Cheran were selling wood but they paid only once. When the loggers (from outside) knew their way in, they started going into the forest [to cut wood]and they did not pay; they had big-ass guns in their hands! Do you think [the people] could confront them?" Mr. Javier, Forest Authority from 2008 to 2011

According to the interviews, the CBC attempted to stop the deforestation, but they lacked enough people and/or arms to effectively fight the external loggers. In addition, they did not have judicial authority; all they could do was to denounce the offenders to the State authorities. Some of the interviewees mentioned that in the rare occasions that the SAMARNAT caught loggers, they were released shortly after by paying a fine. Then, the members of the CBC became the target of criminals' retaliations and some of them were killed. Some forest claimants decided to sell their trees at lower prices before they were taken away violently. Under such circumstances of weakened institutions, Cheran lost approximately a third of its forest.

"We had a lot of problems with the loggers, when they saw our vehicle, they shot at us. We were armed too… I told the governor we needed backup from the State police [Because the loggers are heavily armed], we needed a hand because we were only four against the world" Mr. Javier

Before this, community members not belonging to the forest users' group, were not very involved in forestry matters; however, they started suffering because of the violence and they became increasingly concerned about predatory deforestation. The situation became highly tense when the deforested area almost reached a water spring that provides a significant portion of the community's domestic water. People were afraid that further deforestation would affect their water supply and such fear triggered the mobilization, as one of the leaders of the mobilization states:

"a water spring supplies a fundamental portion of the township water and when [the deforestation]reached that point is when people said –we will be left without water- and so the movement started" Mr. Rafael, leader of the mobilization of 2011

At the beginning of the armed resistance, during the first days of April 2011, a group of women confronted the driver of a truck that transported logs extracted illegally, the women demanded the intruders to stop extracting wood from the forest, they received insults for an answer. But the group did not give up and started encouraging their neighbors to act against the loggers. The neighbors supported those brave women and soon the whole community joined the violent resistance, detaining intruders and burning their vehicles. The people used whatever resources they had available to defend their territory, including rocks, machetes, fireworks and some firearms. In the following days, they were able to control the two main points of access to the community with barricades, but the community became isolated to the outside world. Meanwhile, the community received support (food, money, and arms among other things) from neighboring communities, as well as from people from Cheran living in the US.

That same year, after achieving the security of their territory, the community members of Cheran refused to participate in the State elections and sued the Federal Electoral Institute (IFE) for their rights to elect their own authorities according to their traditional indigenous customs. The lawsuit against the IFE was resolved by the State Electoral Tribunal which is the government branch in charge of settling election-related legal disputes in the State of Michoacan; they ruled against Cheran. Then the community took the case to the Federal Electoral Tribunal which ruled in favor of the new governance system for Cheran. After that, IFE's role in Cheran's elections is only as s supervisor of the process. The new governance system is more horizontal as they elect 12 people (four from each neighborhood) to perform the tasks of a municipal president. The elections are a public ceremony in which supporters of the different candidates form a line behind their candidate of choice and the four candidates with most supporters in line are elected within each neighborhood. The 12 elected people serve for three years; at the time this research was conducted, the second period under this governance system was ongoing.

Forestry management was at the core of the mobilization and continues to be an important issue for the communal assembly. Despite many difficulties, the community has managed to undertake reforestation projects, they also organized an armed group for the protection of the forest. Furthermore, several communal enterprises have been created not only for forestry-related activities, but also for all kinds of business aiming to bring money to the local economy.

> *"Now there are people in charge for each activity, we make sure that everything is accomplished. The community has realized that we must work collectively instead of individually. The activities are efficient and transparent"* Mr. Jaime

5.2 Forest empowerment

As mentioned earlier, the new governance structure is more horizontal, and authors describe it as participatory and decentralized, and where accountability is a priority of the new

administration (España-Boquera & Campo-Jiménez, 2016; Rojas, 2012; Ventura Patiño, 2012). I was interested, however, in investigating the empowerment process in relation to the natural resources, more specifically, the forest.

The interviewees perceive an increase in people's authority over natural resources since 2011, particularly in terms of power to enforce rules. The mobilization in Cheran was a response to the lack of accountability and violence; therefore, rule compliance is a priority of the new government. Before 2011, the power to enforce rules resided in the State of Michoacán's police and courts which, according to the people of Cheran, were deficient. In 2011, the community created their own police force that in 2016 consists of 120 armed subjects that patrol both the forest and the urban area. The police monitor the extraction of firewood and wood, but also ensure the security of the territory. Offenders are referred to the department of Justice of the Municipal government.

"SEMARNAT and PROFEPA[4] never engaged in their duties; it was their responsibility to protect the forest by law" Mr. Javier

"At the beginning of the movement, an [armed] group was created for security reasons…they went ahead of the reforestation brigade to protect them… [The group] assumed the figure of rangers" Mr. Jaime

The community of Cheran shares the power to create laws with the State and the Federal government. The local authorities create local laws that apply to Cheran, but forest use is also subject to federal Laws. For example, wood extraction projects must be submitted to CONAFOR for approval. In contrast, most of the power to enforce laws is decentralized, which means that the community is in charge of enforcing the law and punishing criminals. In Mexico there are two

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[4] PROFEPA (*Procuraduria Federal para la Proteccion del Ambiente)* the judicial branch of the government in charge of enforcing environmental law nation wide

types of police groups, one belongs to the judicial branch of government and one belongs to the executive branch. The state of Michoacán unified all the police forces of the State to increase accountability. However, Cheran refused to join that initiative and maintained an autonomous police force. The local government of Cheran has a branch that sanctions law offenders and it consists of a judge and a group of rangers. The CBC also sanctions those who do not follow the forest rules. The community is so confident on their judicial system that they do not collaborate with the national army, the State judicial police, the State courts, or the Federal Attorney of Environmental Protection (PROFEPA).

Before 2011, the creation of rules for the forest management or legislative power resided in the PROFEPA. After the establishment of the autonomous government in Cheran, the general assembly of neighbors gained significant legislative power. The following quotes show that

"In 2013, we [the current CBC] presented an initiative for extraction of wood apart from resin and it was approved [by SEMARNAT], but the community, the assembly did not approve it" Mr. Roman, CBC stuff member

"We can't decide, the assembly decides whether the extraction [of wood] is done in each area or not" "The assembly is our highest authority" Ms. Josefina Forest Local Authority

According to the interviews, all the legislation is democratically decided by the people of Cheran through the assembly and the execution of forest-related decisions is the duty of the Council of Common Goods (CBC).

Before 2011, the executive power resided in the CBC and currently the Council is still in charge of executing the decisions that people make in relation to forest management. The Council authorizes the extraction of firewood through individual paid permits; they give permission to take wood from fallen and sick trees; and they administrate the reforestation programs. When it comes to make more important decisions like large-scale wood extraction, the CBC must get the approval

of the municipal and state authorities. But the structure of the CBC radically changed since 2011, it became more horizontal and it is more integrated to the municipal government and the General Assembly of Neighbors (GAN). Although the CBC is independent from the municipal government, it is highly accountable to it and to the GAN.

> *"They [the CBC] are in charge of designing projects and we only approve them"* Mr. Rafael

> *"After the movement, a traditional form of government was reactivated, the community decided to have a representative from each neighborhood, each representative has the same faculties and directive rights,"* Mr. Jaime

Table 8 presents the types of power (legislative, executive, and judicial) and summarizes how the community gain power in each of these aspects by comparing what was happening before and after the mobilization of 2011. I symbolize a visible gain of power with "+" and a remarkable gain of power with "++". From Table 8 we can conclude that the Community of Cheran gained overall power in relation to the forest, especially in terms of power to enforce law and execute decisions.

Table 8: Change in power (Empowerment) after the mobilization of 2011

Type of power	Functions	Actors		Community empowerment	Comments
		Before 2011	After 2011		
Power to create laws	Create laws that regulate the extraction of resources at large scale for profit	SEMARNAT (De jure)	SEMARNAT, GAN	+	The SEMARNAT continues to be the highest authority in relation to natural resources and environment law, however, Cheran has dramatically increased its bargaining power. GAN can block wood extraction even if SEMARNAT authorizes it.
	Create appropriation and provision rules for the extraction of resources at domestic scale	CBC (De jure)	GAN	+	Before 2011 the CBC determined the rules for the extraction of firewood and resin from the common property. Nowadays the general assembly votes such rules

Table 8 (cont´d)

Power to make and execute decisions	Manage the extraction of fallen and sick trees	No one	CBC	+	This activity was approved by SEMARNAT and the GAN but the CBC executes it
	Manage the extraction of firewood	No one	CBC	+	The AG granted the CBC faculties to extend permits for the extraction of firewood
	Create reforestation programs	No one	CBC	+	The AG instructed the CBC to reforest the damaged areas.
	Resource monitoring	SEMARNAT (De jure)	CBC	++	Now days the CBC is in charge of monitoring the condition of the forest
	Design and execution of maintenance plans (Fencing, road maintenance, etc)	CBC (De jure)	CBC	+	
	Monitoring of users and boundaries	State police (De jure)	Cheran Rangers	++	Before 2011 the boundaries were very loose. Now days the community has full control of the boundaries.
Power to enforce laws	Sanctioning offenders	SEMARNAT (De jure)	CBC, Cheran Department of Justice	++	Minor infractions are sanctioned by the CBC whereas recurrent and serious infractions are remitted to the Cheran Department of Justice
	Conflict resolution	CBC, State courts	CBC, Cheran Department of Justice	++	The CBC settles disputes among forest users and claimants; the disputes are usually about land. In the past, complicated cases were taken to the state courts and notaries; nowadays the CBC settles all disputes with the help of legal advisors.

5.3 Forest management institutions

Resource and Users Boundaries

Perhaps, the most pressing demand of Cheran inhabitants that mobilized in 2011 was the establishment of clear boundaries for both the forest and legitimate users; therefore, it is not surprising that this subject showed a significant improvement after the mobilization. In 2011, the limits of Cheran's forest were not well marked in the terrain. Not only the fences were obsolete, but the intruders destroyed many of them to facilitate their illegal activities. Thus, one of the first projects that the new CBC undertook was the rehabilitation of the barriers. They reviewed original

documents to determine the limits and hired local people to build fences. In the areas of the forest where intruders kept logging despite the barb wire fences, they dug trenches in order to prevent trucks from trespassing, making it more difficult for outsiders to cut trees. Cheran has conflicts with three other communities in relation to the location of limits for an approximate total of 100 hectares.

> *"At the beginning of the reconstruction process, the first thing we did was cleaning the border [external limits of the community]* Mr. Jaime

The *de jure* owner of the forest in Cheran is the whole community; however, the *de facto* owners before 2011 were the user group which is comprised of approximately 1200 people. In general, people outside the forest user group did not feel entitled to the forest and its resources. That changed during the 2011 mobilization in which the whole community participated in the armed resistance. Thus, after the mobilization, the community has shown more interest in the forest. The forest users' group of Cheran is integrated by claimants or *posesionarios;* they have the right to extract resin from an individual plot, but they cannot extract timber nor sell the land. The claimants most of the time inherit their rights to use the land; however, other members of the community can ask for the rights to a plot of land that no one is currently using, if the community approves the ask, they are given a responsibility to take care of the plot. Although the forest user group of Cheran continues to be the claimants, the entire community exercises now *de facto* ownership of the forest.

> *"They are not owners; they are claimants… the land is owned by the whole community"* Mr. Jaime

In addition to fencing the external boundaries of the forest, the internal divisions of the forest were marked with fences as well. Approximately 90% of the forest is claimed by members

of the community, the remaining 10% of the forest is commonly owned and no one has the right to withdraw resin from it. The tenure claimers hold entitles them to the exclusive right to manage the production and withdrawal of resin from the trees. However, the community as a whole retains the ownership of the forest as well as the right to make decisions about logging and changes in soil use. The CBC extends certificates of tenure to the claimants when they require it; such certificate specifies that despite being granted the rights related to resin extraction, the ultimate ownership of the land stays with the community. Claimants have the right to extract resin from a defined plot; however, the individual plots within the forest are not usually fenced by barbed wire because claimants verbally agree on the limits. However, when a reforestation program is implemented in an individual plot, fences are constructed to keep livestock from entering the plots and prevent saplings to be harmed.

> *"Some people still think that it is private property but after the movement we acknowledge that they are not private properties… they are not owners, they are only claimants" "We give them maps [of the claimed land] but the document clearly states that the community owns the land"* Mr. Roman, member of the CBC staff in 2016

After 2011, in Cheran all people from the community are considered forest users as they can withdraw firewood with a permit from the CBC. They can also collect herbs and mushrooms freely in all the forest. Community members can also have livestock ranging in the forest. Therefore, rangers allow the free transit of members of the community in the forest. However, the community patrols the forest looking for people that withdraw firewood without a permit or carry green wood. The rangers are especially concerned with outsiders extracting anything from the forest or even trespassing it. Even though the population of Cheran is numerous, the rangers are very confident that they can recognize members of the community from outsiders very effectively.

After 2011 there was an important enhancement of the user boundaries. Before the mobilization, virtually everybody could enter the forest and extract as much of the resources as possible. At the worst point of the situation, loggers did not even hide their activities; they transported stolen wood through the township during the day. The CBC tried to stop illegal logging, but they lacked the resources and the personnel to make an impact; the president and his assistants themselves oversaw patrolling. Even when they caught criminals, there were no consequences because they lacked the authority to incarcerate the offenders and the State authorities kept ignoring the problem. There is also the presumption that local authorities were involved in the illegal logging either by complicity or by intimidation.

"Those people [external loggers] made roads everywhere to extract wood, they did not respect the fences, they were all torn down" Mr. Jaime

At the core of the mobilization was the demand of stopping intruders from logging in Cheran. At the beginning of the conflict, a community guard group was set in place to defend the territory from outsiders, with whom the community guard group had several violent encounters. The community guard survives to date and serves as police and forest rangers. These armed guards obey only local authorities and they patrol the perimeter of the forest and the urban area.

"Neighbor communities sometimes enter the forest and cause damages so the rangers' group was created; they are part of the community and their duty is to monitor the territory" MR. Roman

Thanks to the secured boundaries and the permanent surveillance, the number of intruders has dropped dramatically since 2011. In 2015 only isolated cases of illegal logging in Cheran´s forest by outsiders were registered. Internal monitoring for the compliance of usage rules is now the main activity of the forest rangers.

Appropriation and provision rules

Appropriation rules were in place before 2011; however, they were improved after the empowerment process. Table 9 contains a description of the appropriation rules for each forest product before and after 2011. The National Forestry Commission (CONAFOR for their Spanish acronym) grants extraction licenses for commercial purposes under a supervised forestry plan. Commercial extraction has not been allowed by the CONAFOR in Cheran since the 80s. In 2012, the CBC got an authorization to extract fallen and ill trees to clean the forest; the wood was turned into boards and sold locally. No one besides the CBC is authorized to extract lumber in Cheran.

Table 9: Appropriation rules

Product	Rules before 2011	Enforcer (Compliance)	After 2011	Enforcer (Compliance)
Lumber	CONAFOR did not allow anybody to extract lumber.	SEMARNAT (No)	CONAFOR authorized the extraction of ill and fallen trees; this activity is carried out exclusively by the CBC.	CBC, Cheran rangers (Yes)
Firewood	There were no rules for the extraction of firewood	N/A	Cheran inhabitants are granted permission for the extraction of a certain amount of firewood in a weekly basis; they must pay a fee.	CBC, Cheran rangers (Yes)
Resin	Only claimants can extract resin in their plots.	Each claimant (Yes)	Only claimants can extract resin in their plots.	Each claimant, CBC, Cheran rangers (Yes)
Mushrooms and herbs	No rules	N/A	No rules	N/A
Grass (For livestock)	Livestock can range freely in all the forest	N/A	Livestock can range freely in all the forest. Each claimant is responsible for the fencing of his plot to avoid damages to the young trees. Therefore, fences are installed when the trees are young.	CBC (Yes)

Pieces of wood under 35 cm in length are considered firewood. After 2011, a set of rules for firewood extraction were established. All inhabitants of Cheran over the age of 18 have the right to extract firewood from any place in fallen trees in the forest if they pay their permit. The CBC grants permit to extract firewood at different prices and frequencies, depending on the transportation method as shown in Table 10.

Table 10: Firewood extraction rules

Transport	Cost	Frequency of extraction
Pick-up truck loaded with firewood.	15 pesos	Twice per week
Wagon (small animal-traction car that carries approximately half of the load of a pick-up truck)	10 pesos	3 times per week
Equines (Horses and/or donkeys that carry firewood in their backs)	10 pesos	4 times per week

Resin extraction has a long tradition in Cheran; however, this activity was in decay before 2011 due to the high deforestation rate. Thanks to improved safety, a healthier forest and a rise in prices of the product, resin extraction became more profitable and claimants resumed the extraction activity. Only claimants are authorized to extract resin in their plots, and they are in charge of the management. All the resin is collected in a commonly owned enterprise that separates the liquid and solid parts and sells both to the industry. The enterprise is owned by 100 forest users and administrated separately from the CBC.

> *"[Claimants]have the right to the products and to work in the forest, if it is agriculture land they can put crops, if it is forest they can extract resin but they cannot make any other kind of extraction like trees, sand or gravel, that requires the approval of the council, of the community"* Mr. Roman

Besides the main forest products (lumber, firewood and resin), mushrooms and herbs are extracted from the forest; however, there are no appropriation rules for these goods, meaning that

anyone can extract them from the forest and as much as they want. Herbs and mushrooms are collected by Cheran inhabitants both for self-consumption and for commercialization.

> *"You [anyone in the community] can go search and extract mushrooms or herbs but you cannot damage or extract wood… as for the resin, you cannot [extract], each claimant works, makes grooves [on the trees for resin extraction] and extracts [resin] in their own land"* Ms. Josefina, Member of the CBC stuff

Provision rules refer to the way each common owner contributes to the group and the management of the forest. Before 2011, reforestation and fencing activities were the responsibility of each claimant, while the CBC oversaw fixing the roads that allow transportation within the forest. Traditionally, all claimants are obligated to help stopping fires in the forest in case these occur. Since 2011, the CBC oversees the maintenance of the forest; they manage the reforestation, fencing and maintenance of roads. The CBC obtains money from selling wood, construction materials from the mines[5] and trees from the plant nursery; additional to resources that come from firewood permits and federal grants[6]. With that money the CBC pays for the wages of its members and provides employment to around 200 people from the community to work in reforestation and fencing programs.

Collective-Choice arrangements

As explained in the section on empowerment, the community gained a lot of authority over the governance of their natural resources after 2011; many of the decisions are now made by the

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[5] Besides timber, resin, herbs, mushrooms and cattle food, the forest of Cheran also produces construction materials from digging sites or mines. The CBC is in charge of the administration of such mines.

[6] Mexico has several subsidy programs for the rural sector. Initially, Cheran had difficulties accessing to such subsidies; however, thanks to a very good internal organization they now get federal resources for reforestation campaigns, soil conservation programs and environmental services payments.

community or they are negotiated with the National government. Inside the community, decision making with regards to forest decisions has always been democratic in the sense that the general assembly of forest users is the highest local authority; however, before 2011 the local authorities had little to no *de facto* power. After 2011, the democratic mechanisms for decision making were strengthened and the general assembly of forest users gained more power. This assembly makes important decisions and elects an operative team (CBC) via elections. After 2011, the governing system became more horizontal as it was described before. Instead of choosing a single president with its secretary and treasurer, the community elects 12 people to conform the CBC with equal representation from each of the four neighborhoods of Cheran. All members of the CBC share equal authority although there is one person that serves as president for legal and administrative purposes. All bureaucrats in Cheran are required to come from the roots of the 2011 mobilization; they are elected by and hold accountable to the neighborhoods' assemblies through regularly scheduled evaluation meetings. The appropriation and provision rules, sanctions and decisions about the reforestation activities are all submitted to vote in the general assembly.

> *"The community decided to have representatives from all neighborhoods. Each representative has the same faculties and directive rights" "Instead of one president, there are three 'presidents' from each neighborhood for a total of twelve in the council"* Mr. Tomás, CBC member

Monitoring of the resource and the users

Before the mobilization of 2011, no one was monitoring the condition of the forest even though the law says that the SEMARNAT oversaw this activity. Estimations of the total area deforested were made by the community once they recovered control of the territory in 2011; the new CBC has personnel to monitor the forest and quantify the areas that needed to be reforested.

Once the community recovered full control of the forest, they started to try to restore the damaged land. Thanks to their organization they were able to negotiate with CONAFOR, SEMARNAT and other governmental organizations to obtain federal funding for their reforestation programs. The community had to negotiate for more than one year before their rights were recognized, but nowadays they have a close relationship with the federal forest organizations. Applying for new funding for reforestation requires the compliance of a minimum of survival rate in the new plants; therefore, both the community and the federal government closely monitor this indicator.

> *"Every year they (CONAFOR) come and verify the planted surface and the survival rate. They come and verify everything and based on that they renew the subsidies"* Mr. Roman

In 2013, the CONAFOR surveilled the forest and determined that it was possible to implement a forest extraction plan without compromising the integrity of the forest; logging was planned for areas that were not affected by the deforestation during the 2005-2011 crisis. In case of implementing the plan, CONAFOR would have intensified the monitoring. However, the general assembly of Cheran municipality voted against the implementation of the plan and decided to focus only on reforestation.

> *"In 2013, we submitted a project for a timber and non-timber extraction plan (on top of the resin) and it was authorized; but the community, the assembly did not want it"* Mr. Roman

Users monitoring was greatly enhanced after the empowerment of Cheran's people. The forest rangers' squad was created mainly to prevent outsiders from entering the forest, but nowadays they are also in charge of monitoring compliance of rules by claimants. The territory is constantly patrolled to identify and arrest offenders. People carrying firewood are required to show a valid

permit. No one besides the CBC personnel can cut trees of any type or transport pieces of wood bigger than 35 cm in length. Monitoring the extraction of pine and oak is very effective because these woods are valuable in big pieces and therefore easy to spot. More precious woods, on the other hand, are easily hidden form the rangers, which makes them more vulnerable to logging for commercial purposes. Offenders are arrested and sent to the CBC, where they are given the corresponding sanction.

Graduated Sanctions

Before 2011, minor sanctions were applied by local authorities, while loggers' punishment was a responsibility of State authorities. According to the testimonials of forest users, illegal loggers were not held accountable by the SEMARNAT. With the new governing structure, the community took control over the sanctioning and judicial system. Nowadays, if somebody is found extracting wood without a permit for the first time, the forest rangers confiscate the offender's tools and vehicle. After paying a fine of up to $100 USD to the CBC, the tools and the vehicle can be recovered. The second time someone is caught violating forest rules, firewood permits are denied for one month, in addition to a $100 USD fine. After a third time, people are sent to the department of justice, which is the judicial branch of the municipal government in Cheran. In such cases, the department of justice determines a more severe sanction such as jail time or permanent confiscation of the tools and vehicle.

> *"We have rangers, they confiscate the tools of the intruder and we write a report. We determine a sanction depending on the magnitude of the offence: the greener the wood the bigger the fine. If the logger has a record, the fine is bigger. The sanctions go form $5 to $100. When they pay they get their tools back" Mr. Tomas*

Conflict Resolution Mechanisms

According to former authorities, adjudication of disputes was happening efficaciously before 2011; however, this trend has seen improvement since the mobilization. Previously, the officials relayed in their own experience and local knowledge to settle disagreements between forest users and they had some success. After 2011, however, the CBC hired a specialized lawyer to assist with all legal issues. This lawyer interprets the agrarian reform law for them. Most conflicts relate to property rights; although claimants do not own the land, they have disputes over the usufruct rights of forest plots. Sometimes, two different people claim to have the property rights over the same plot; the CBC reviews the existing documentation; determines who is the claimant and releases new documentation.

> *"We resolve conflicts about plots among claimants…..Sometimes, the claimant*
> *of a plot abandons it for some years; when he comes back someone else is*
> *using it. We have the authority to solve this with the advice of a representative*
> *from the Agrarian Reform Bureau"* Mr. Tomas

The community does not have written rules for settlement of disputes. The CBC deliberates based on interpreting the existing legal documents with the advice of their lawyer. The interpretation and validation of legal documents is important because in the past several legal entities had issued property rights documents to forest users. The old CBC sometimes settled disputes and gave legal documents to claimants with no solid legal basis. Similarly, the State notaries had issued documents that entitled forest users to full property rights. Currently, the CBC issues property rights documents that override the old ones and the ones from the State notaries. In the new legal documents, it is clearly stated that the ultimate owner of the land is the community and claimants only have usufruct rights over the land.

> *"We measure [the plot] using a GPS, then we make a document with a map in which we clearly state that the community ultimately owns the land"* Mr. Roman

Recognition of Rights to Organize

All over Mexico, *Ejidos and comunidades* have always had rights to organize to manage their natural resources. In Cheran, before 2011, the forest user group elected their authorities according to the rules established by the agrarian reform bureau, the instance that deals with legal issues related to land property. The law establishes that all user groups must have a president, a secretariat and a treasurer, as well as a monitoring body composed of three people. After 2011, the community of Cheran decided to substitute the governing structure with a more horizontal one as described earlier. Since the new structure is not exactly the same as the one specified by the national law, the new CBC struggled to gain recognition by higher levels of government.

> *"They told us: 'In the agrarian law there is not a structure like yours, only a [single] representative but not a council so we cannot recognize you'" "'We cannot give you a document saying that you are the authority'"* Mr. Rafael

The lack of recognition by superior authorities delayed the community's access to federal funded programs for reforestation and development. After a year of litigation, the CBC was finally recognized, but every time the community elects new authorities, the general assembly must get together and ratify its validity under the supervision of the Agrarian Reform Bureau. Currently, most organizations recognize the CBC as Cheran's operating authority; therefore, they have access to diverse federal programs.

> *"We negotiated with the federal institutions for a year and a half to solve our situation and finally being a legal figure"* Mr. Tomas

Nested Enterprises

According to Ostrom (1990) appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities must be organized in multiple layers and be consistent among them. Before 2011, all institutions were in theory fully nested as the forest user group was under the control of the municipal administration. Similarly, the municipal government was subordinated to the State and federal governments. After 2011, when Cheran established their autonomous municipal government, the nesting of organizations went through several changes.

Within the community, the organizations became more integrated after 2011 as the forest user group authorities work closely with the municipal authorities; both are elected through identical mechanisms by the general assembly of neighbors. The CBC manages the forest and common enterprises (plant nursery, mines, and sawmill) except the resin processing plant which is run by a hired manager. The resin processing plant was functioning well before the mobilization of 2011 and therefore remained outside the new governing structure.

The nesting of municipal institutions within higher levels of government decreased after 2011. The municipality became independent from many State and federal instances, such as the federal electoral institute and the police. Cheran's police force does not coordinate with the federal army nor the State police. The State notaries do not coordinate with the CBC and even in some cases, they write contradictory legal documents in relation to the property rights of the land. The lack of coordination often leads to conflicts. For example, one plot of land can have two separate sets of documentation that give property rights to different people leading to disputes among forest users.

Initially, the federal entinites that dealt with forest matters such as CONAFOR and SEMARNAT did not cooperate with the community. However, thanks to the organizational

capacity that Cheran has shown, the community now has a close relationship with the federal government when it comes to forestry. Cheran is now portrayed as a model of sustainable community forestry system by the same federal organizations that refused to help the community during the deforestation crisis.

Figure 5 shows a map of the many entities involved in the governance of Cheran and how they relate to each other. Inside Cheran municipality, all entities are fully nested and work with each other. In contrast, Cheran is not fully coordinated or nested with the federal and state government. In some respects, such as health administration, Cheran heavily depends on higher levels of government. In other aspects, local authorities do not coordinate with their federal counterparts; a good example of this is the armed forces. In figure 4, two entities are fully nested when one is inside the other. Cheran is not fully nested within the federal government, therefore, the corresponding rectangles only overlap. Two entities are separated but perfectly coordinated when linked with a solid line; that is the case of the mill and the resin plant. A dashed line, however, means that two entities known about the existence of each other, but they do not coordinate at all. Such is the case of the federal armed forces and the rangers of Cheran; they recognize each other´s existence but do not communicate or coordinate at all.

Figure 5: Nesting of Enterprises

52
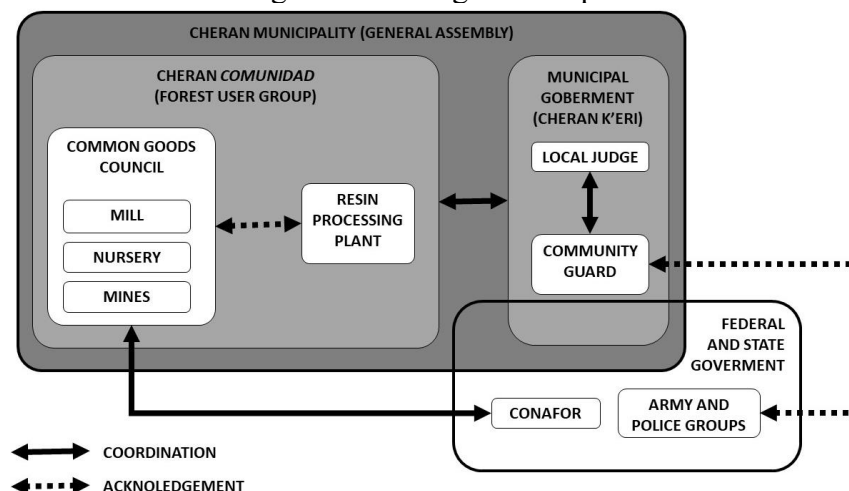
5.4 Landcover Change

I applied the GEE algorithm to six different years between 2005 and 2020 and obtained the accuracy indicators shown in Table 11. The values for validation Kappa ranged from 82.09% to 92.63%

Table 11: Accuracy parameters of the supervised classifications.

Year	Accuracy indicators				
	Classification Data	**Bare Soil**	**Transition**	**Forest**	**User Accuracy**
2005	**Bare Soil**	101	6	24	77.10%
	Transition	0	535	69	88.58%
	Forest	0	0	250	100.00%
	Producer Accuracy	100.0%	98.9%	72.9%	Kappa: 82.09%
	Classification Data	**Bare Soil**	**Transition**	**Forest**	**User Accuracy**
2008	**Bare Soil**	101	6	24	77.10%
	Transition	0	535	69	88.58%
	Forest	0	0	250	100.00%
	Producer Accuracy	100.00%	98.89%	72.89%	Kappa: 88.37%
	Classification Data	**Bare Soil**	**Transition**	**Forest**	**User Accuracy**
2011	**Bare Soil**	130	**0**	1	99.24%
	Transition	6	566	32	93.71%
	Forest	0	4	246	98.40%
	Producer Accuracy	95.59%	99.30%	88.17%	Kappa: 92.13%
	Classification Data	**Bare Soil**	**Transition**	**Forest**	**User Accuracy**
2014	**Bare Soil**	129	2	0	98.47%
	Transition	10	559	35	92.55%
	Forest	1	8	241	96.40%
	Producer Accuracy	92.14%	98.24%	87.32%	Kappa: 92.63%
	Classification Data	**Bare Soil**	**Transition**	**Forest**	**User Accuracy**
2017	**Bare Soil**	127	4	0	96.95%
	Transition	26	535	43	88.58%
	Forest		7	243	97.20%
	Producer Accuracy	83.01%	97.99%	84.97%	Kappa: 85.64%
	Classification Data	**Bare Soil**	**Transition**	**Forest**	**User Accuracy**
2020	**Bare Soil**	130	0	1	99.24%
	Transition	10	555	39	91.89%
	Forest		2	248	99.20%
	Producer Accuracy	92.86%	99.64%	86.11%	Kappa: 90.56%

Table 12 and figure 6 show the area per class in square Km in the territory of Cheran outside the agriculture land and urban areas, from 2005 to 2020 in three-year intervals. Healthy forest reached its lowest point in 2014 and by 2020 recovered to around 90% of its original extent. Bare Soil also reached its highest point in 2014.

Table 12: Land cover change

Class	2005	2008	2011	2014	2017	2020
Bare Soil	10.84	14.62	17.38	25.27	19.75	22.97
Transition Forest	24.50	25.54	32.02	39.22	35.14	23.58
Healthy Forest	140.60	135.78	126.53	111.46	121.05	129.39

Figure 6: Land Cover Change within the Forestry Areas of Cheran
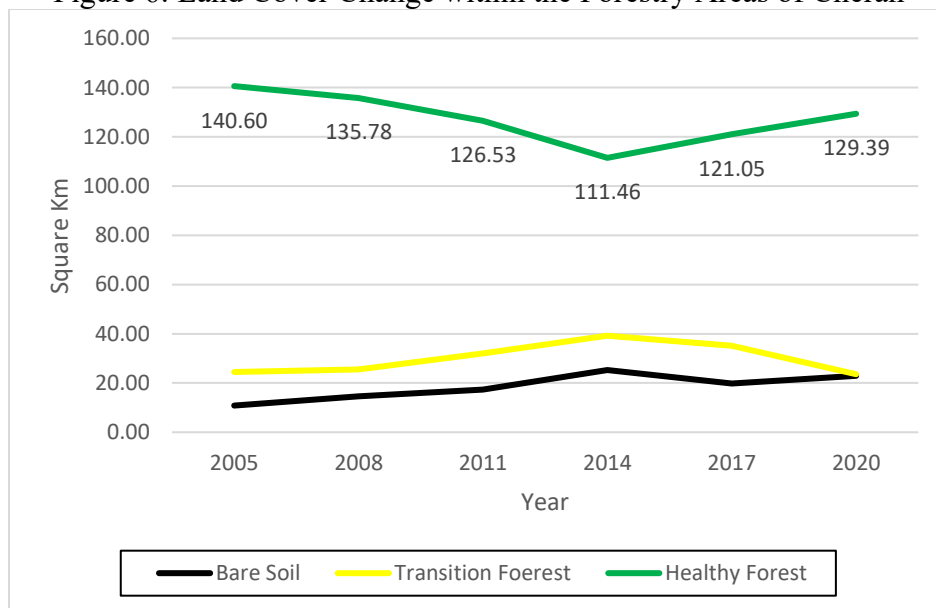
From Figure 6 we can learn that during the deforestation process, healthy forest was substituted by both bare soil and transition forest. However, during the most recent years, the missing forest is mostly accounted by bare soil. This might be the result of planned campaigns of timber extraction in which big plots of land are cleared but quickly recover to healthy forest. Despite the progress, healthy forest land cover is yet to come back to the level of 2005;

unfortunately, I don't have an explanation for that and a second visit to the field might be necessary to understand the processes behind it.

Figure 7 shows the areas covered by bare soil, transition forest and healthy forest at different points in time. It is clear that big areas of forest were substituted by bare soil and transition forest in 2011 and 2014. In 2020, there is an increased area of bare soil, however this are well defined regions which might mean that those areas were used for the planned extraction of timber.

Figure 7: Maps of land cover by class
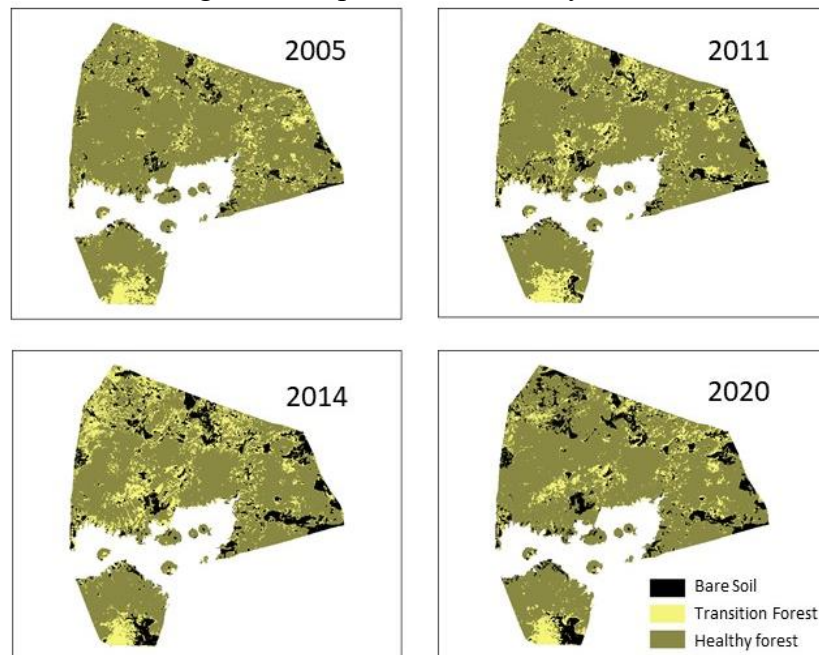
6. DISCUSSION AND CONCLUSION

In the literature, empowerment is widely used and defined in several ways to the point that some authors consider it a buzzword (Cornwall & Brock, 2005). However, the case of Cheran demonstrates that empowerment is a phenomenon that can be observed and has implications for governance, environmental sustainability and the wellbeing of the community. In Cheran, empowerment manifested as the community's increased authority over the management of natural

resources. After 2011, the forest user group gained power to create, execute and enforce rules for the usage of the forest. Therefore, the case gave me the opportunity to empirically assess the process of empowerment and its positive consequences for the sustainability of the forest. This research work did not include a formal assessment of the empowerment´s consequences on social and economic aspects of sustainability; however, from my observations I can tell that the community was improved overall thanks to the process of empowerment. Therefore, future research on the topic of empowerment, should look at its concrescences for sustainability in general.

Mexico decentralized forest management in 1992; however, as shown in the case of Cheran, the policy implementation did not actually transfer powers to local communities. Before 2011, the forest user group in Cheran held no judicial power and incomplete legislative power; their authority was basically limited to executive power. Larson & Soto (2008) argue that it is precisely the lack of community empowerment that hinders decentralization's potential to deliver positive social and environmental outcomes. The case of Cheran presents solid evidence to support such argument because in many ways the lack of power by the community caused the deforestation crisis of 2005-2011. Because the community did not have judicial power; they relied on the State authorities to hold illegal loggers accountable. However, according to the local authorities, the State judicial system did not sanction or incarcerate the intruders due to corruption. Certainly, other factors such as violence contributed to the deforestation of Cheran; however, the lack of local power played a critical role.

Form this research we can conclude that decentralization policy not always includes an actual transfer of power to local communities which hinders its potential to deliver positive environmental and social outcomes. In the literature, decentralization and empowerment are

sometimes defined similarly as both concepts are related to a change in power. I argue that decentralization is a top-down phenomenon while empowerment happens in a bottom-up fashion. Empowerment in Cheran happened because the community mobilized to grab power and found from resistance from the top. This antagonist relationship between empowerment and decentralization should be taken into consideration in future research about the topics.

Decentralization and community self-empowerment need to be supported by the centralized power. Therefore, the success of self-empowered, community-based natural resource management depends on the communities' ability to negotiate with regional and national governments. It is therefore a perfect example of polycentrism. But it does not need to be as difficult as it was for the community of Cheran.

Merino (2017) studied the process of peace building in Cheran and argues that even though the State plays a fundamental role in the administration of the commons, "social and community participation are indispensable for the defense, restoration and re-creation of diverse common goods " (Merino & Cendejas, 2017, p. 924). However, the participation of the community of Cheran became relevant only after the process of empowerment; therefore, I consider it essential to investigate this process.

According to Gibson et al (2000), a fundamental condition for sustainable management of CPRs is that users must highly value the natural resource. This is consistent with what I observed in Cheran because a big sector of the local economy depends on the production of resin. Furthermore, the stakeholders reported that the mobilization was triggered by the possible destruction of their source of drinking water which is in the forest. Other communities of the state of Michoacán do not value the forest as much because they have substituted it with avocado plantations. Nowadays, avocado plants are prohibited in Cheran but even before the mobilization

of 2011 no commercial plantations were established in the territory, which gives us an idea of how much the people of Cheran value their forest.

In addition to the high value that the forest represents for the community, high levels of social capital can explain the success of the mobilization as theorized by some authors (Bray et al., 2003; Ellis & Porter-Bolland, 2008; Pérez, 2003). Cheran has a strong indigenous identity and a history of subversive movements; additionally, most of the population lives in a single urban area which facilitates communication. I argue that all those characteristics of the community allowed them to coordinate their efforts in response to the obvious degradation of their forest; however, my research is focused in the consequences of the empowerment rather than its causes.

The case of Cheran presents insights into the topic of institutional development which is key for the literature of CPR sustainability. Ostrom's design principles once more proved to be a useful framework for the analysis of CPR institutions. I found that each of the principles was relevant for Cheran and the needs of the stakeholders. As noted by Agrawal (2001), the first six of Ostrom's principles focus on local institutions whereas the last two focus on the relationships within the local context; that distinction is especially relevant in the case of Cheran. After 2011, the local institutions in the community very quickly evolved to resemble Ostrom's principles; on the other hand, the community struggled to establish robust relationships with higher levels of government. Nowadays, Cheran is recognized as an example of sustainability in Mexico and the National Commission of Forestry is very supportive of the community. The recently elected President of Mexico, Andres Manuel Lopez Obrador is known for its leftist policy and willingness to support indigenous communities which most likely strengthened the relationship of Cheran with the federal government.

The assessment of land cover change reveals a scenario that matches the narrative of the people of Cheran. The area with healthy forest decreased drastically during the first half of the 2000s and reached its lowest point in 2014 when transition forest reached its high. Transition is being substituted by healthy forest since 2014; therefore, in 2020, the area covered with healthy forest is at 90% of the 2005 level. The institutions that were established in 2011 have a clearly positive effect in the environmental sustainability of the forest in Cheran. It would be important to continue monitoring the institutions and the status of the forest to understand the effectiveness of this arrangement in the longer term. More so, to study other aspects of sustainability that seem to be positive as well, as economic, and social sustainability. Violence in Mexico continues to be a problem which combined with big changes in the political scenario, could present important challenges to the current institutions of Cheran and test its endurance.

GEE proved to be a powerful and flexible tool for the assessment of land cover change. Even though my assessment of land cover change was satisfactory for the purposes of this research, it can be improved by increasing the temporal resolution of the measurements and the number of included classes. The kappa values of the classifications are acceptable but not ideal. Increasing Kappa values can be achieved with specific training polygons for each year which is not a simple task given the lack of high-resolution imagery for every year of the study. Another factor affecting kapa values is the similarity between classes. The model can differentiate forest from bare soil very easily; however, it struggles to differentiate between healthy and transition forest.

After the community of Cheran mobilized to gain their autonomy, several neighboring communities have initiated similar processes. The relevance of Cheran as a case study is increased by this trend in self-empowerment movements. On the one hand, Cheran provides evidence suggesting that increased local authority can result in more robust institutions and reduced

deforestation; in this sense, local self-empowerment movements are desirable. On the other hand, the case reveals the deficiencies of natural resources policy in Mexico: even though the federal government finally recognized Cheran's traditional form of government, it was at a very high cost for the community to the point that they had to use violence to gain power. A more effective transfer of power after forest management decentralization could have prevented the violent mobilization in Cheran and could prevent future uprisings. Cheran's difficulties to fully nest its institutions within higher levels of government suggests that national policy is not polycentric enough to integrate local enterprises and this is a clear contradiction to the theoretical principles of decentralization and to their achievement.

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