Land use and land tenure change in Mexico's avocado production region: Can community forestry reduce incentives to deforest for high value crops?

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ABSTRACT

Rapid land use change in highland pine-oak forests of Michoacan, Mexico is due primarily to conversion of natural forests to avocado plantations. Many privately-owned avocado orchards are found on land that was common forest before the 1992 Reform of Article 27 of the Mexican Constitution, which allowed the division of common land under certain circumstances. In a region with widespread community forestry programs, some communities have maintained forest cover while adjacent communities have deforested extensively. We therefore ask how land use change was facilitated by policy changes that affected systems of common property management. We address this question in a comparative case study of four communities, two with active community forestry programs and two without. We conducted an analysis of land cover change using Landsat satellite imagery and applied interviews and household surveys in case study communities. Results show that 33.1% of forest cover was lost over a 16 year period across the avocado production region. However, the two forestry communities lost only 7.2% and 15.1% of forest cover, while the two non-forestry communities lost 86.5% and 92.4%, respectively. Interview data show that the Reform of Article 27 combined with the 1992 Forestry Law led to the collapse of local governance, illegal division of common forests, and illegal logging in the two non-forestry communities. It was not until several years later that land sales and orchard planting initiated, suggesting that these policy changes were an important catalyst of land use change. Household survey results show that the two forestry communities are slightly wealthier, better educated, less reliant on fuel wood, and have more work opportunities outside of the rural sector. In non-forestry communities, negative experiences with non-participatory forestry programs before 1990 may have led to illegal timber harvests following the Reform of Article 27.

KEYWORDS**:** Community Forestry, Mexico, Land Tenure, Trade, Land Use Change

I. INTRODUCTION

The rapid land use change observed in highland pine-oak forests of Michoacan, Mexico is due primarily to conversion of natural forests to avocado plantations (CEF 2007). Concern over the extent and pace of land use change in

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this region contrasts sharply with tendencies observed in the majority of pine-oak forests in Mexico, in which the land use change rate (1.0%) is lower than that of tropical broadleaf forests (2.1%) (Velazquez et al. 2002). Despite the rapid land use change observed in the region, little has been documented about the ecological, social or economic implications of avocado expansion. No formal analysis of land use change has been conducted, little is known about the process by which communally owned forests are converted into privately owned orchards, and the political economy of avocado expansion and deforestation in the region has not been explored.

Initial anecdotal evidence of land use change processes in the region led to two surprising observations. First, land use change is not evenly distributed across the region. Certain communities have deforested over half of their communal forests in recent years while the forests of adjacent communities remain intact. In a region with community forestry programs of varying degrees of success, the potential relationship between community forestry and the conservation of forest cover is important to explore. Second, according to historical accounts of community members and government officials, rapid deforestation occurred in the region several years before avocado production expanded and began coincidentally with two policy changes: the Reform of Article 27 of the Mexican Constitution, which allowed the individualization and private titling of commonly held lands under certain conditions, and the 1992 Forestry Law, which reduced government oversight of timber transport in an attempt to improve efficiency and liberalize the sector.

These two observations led to the formulation of our primary research question, which we explore in a comparative case study of four communities in the region: How were the expansion of avocado production and land use change facilitated by policy changes that affected systems of common property management? To address this question, we first conduct an analysis of land use change using Landsat TM and ETM satellite imagery to determine how forest cover has changed in a set of four case study communities as well as in the larger avocado production region. We then explore the histories of forest use and land use change in the four communities to understand how policy changes in the early 1990s set the stage for deforestation in certain communities and rapid expansion of production in the early 2000s. Finally, we compare results of interviews and household surveys of case study communities to determine what underlying differences created such varied outcomes for forest cover.

In all, this study aims to further our theoretical understanding of how external influences affect local management of the commons. We suggest that maintaining and enhancing the strength of common property institutions is vital for managing forest resources. However, if these efforts are not made in a policy context that favors common property, the outcome may not be successful. In addition, policy changes in the agrarian, forestry, and agricultural sectors have been a determining factor in debilitating local institutions and creating the

opportunity for subsequent land use change. As these three sectors have been fundamental in creating a situation conducive to rapid deforestation, it seems clear these three institutions will be necessary to create sustainable development in the region.

II. BACKGROUND

Common forests and community forestry in Mexico

With roughly 80% of Mexico's forests under a common property regime (Bray, Merino-Perez, and Barry 2005), effective local governance of commonly owned forests is crucial to maintain ecosystem services and create economic benefits for forest communities. Collective action theory (Olson 1965) as applied to common property (Ostrom 1990) aims to understand the conditions under which groups of people cooperate to manage commonly owned resources. Effective collective action in the commons is influenced by three sets of factors: characteristics of the user group, characteristics of the resource, and external influences (Ostrom 1990). Most research on management of commonly owned forests has focused on the first two sets of factors, including extensive work on rule-making and enforcement, leadership, group size, and heterogeneity, and characteristics of the resource (Ostrom 1990; Wade 1988; Gibson, McKean, and Ostrom 2000; Poteete and Ostrom 2004). Yet the large and growing body of literature on common property management rarely focuses on the third set of factors: external influences on the community. Commons management invariably takes place within a political economic context whose influence in some cases may matter more than internal organization (Agrawal 2001; McCay and Jentoft 1998). According to Ostrom, external governance can either facilitate the creation and enforcement of rules or impede local governance by imposing generalized rules or engaging in corruption. In Mexico, research on the external context of community forestry has focused on failures in management resulting from the lack of coordination between state and local authorities in the Monarch Butterfly Reserve in Michoacan (Tucker 2004); on a local logging ban that created disincentives for sustainable timber management in the Lake Pátzcuaro basin in Michoacan (Klooster 2003); and on federal reforms of land tenure and forestry laws in Durango and Quintana Roo (Taylor and Zabin 2000; Taylor 2000; Taylor 2003). Yet little work has been done that explores whether and how specific policies have changed incentives for land use and affected the ability of user groups to effectively manage resources.

Community forestry in Mexico began in the early 1980s when concessions to parastatal timber companies were nearing expiration and a handful of communities in Veracruz and Oaxaca organized to attain the right to harvest timber from communal forests (ASETECO 2002). Virtually all of Mexico's most successful community forestry programs (Bray et al. 2004; Chapela Mendoza 1999; Velazquez, Torres, and Bocco 2003) were initiated in the mid-1980s as a result of the grassroots community forestry movement and subsequent

government sponsored community forestry development programs. These communities have acquired infrastructure and appropriated many of the activities associated with forest management, including felling and skidding trees, milling lumber in commonly owned saw mills, and in some cases attaining Forest Stewardship Council certification and producing finished wood products. As a result of these success stories, community forestry programs have been promoted widely in Mexico in recent decades, to the extent that they have been called a global model for sustainability (Bray et al. 2003). Yet the majority of communities with forestry programs have not achieved this level of vertical integration of management activities. Of the roughly 250 active permits for community forestry in Michoacan, only about 20% conduct some of the forestry activities mentioned above. The remaining 80% of communities contract their forests to local timber companies and private foresters who conduct all management activities, usually under minimal oversight by the community. Due to the relatively low participation in forestry activities, the stability of forestry programs and the sustainability of management activities are questionable (Jardel 2006). This paper specifically explores the resilience of this type of forest community to external policy change.

Avocado production in Michoacan, Mexico

The avocado region of Michoacan is defined by climatic characteristics that provide adequate moisture and temperature for intensive production of the Haas avocado variety. According to the Avocado Commission of Michoacan (COMA), adequate conditions occur in areas between 1050 and 2600 meters above sea level that receive between 120 and 160 cm of annual precipitation and have a temperature of between 8 and 21º C, representing roughly 12.9% of the surface area of the state of Michoacan (COMA 2007).

While orchard production with improved varieties began as early as 1957 in Michoacan, rapid expansion did not occur until more recently. In the 1968, total surface area of avocado production was 13,350 ha, a figure which grew to 23,000 ha in 1975, 58,800 ha in 1980, 78,500 ha in 2000, and over 86,500 ha in 2006 (COMA 2007; Barcenas Ortega and Aguirre Paleo 2005). Michaocan currently producers over 84% of all avocado grown in Mexico and over 40% of world production (APEAM 2005). Avocado production is estimated to create 47,000 full-time jobs and 70,000 temporary jobs in the region (COMA 2007).

Increases in production over the past decade have been due mostly to a rise in exports to the United States. Since 1914 and prior to 1997, Mexican avocados had been banned from the United States due to the presence of the avocado seed borer (*conotrachelus perseae Barber*) in native avocados varieties. However, since the Mexican domestic market for avocados was strong, there was no need to contest the phytosanitary ban until markets in Mexico began to falter in the early 1990s due to ongoing financial crises. Although avocado growers in Mexico pushed for the lifting of trade bans with

passage of the North American Free Trade Agreement (NAFTA) in 1994, California growers successfully lobbied for the continuation of the phytosanitary ban (Stanford 2005). The presence of the seed borer in Mexican orchards was debated by Mexican and U.S. growers, and Mexican growers accused their California counterparts of creating a pretext for protectionism. Beginning in the early 1990s, an important network of producer and packing organizations, government agencies, and research institutions made it possible for Mexico to successfully argue that avocado exports should be allowed into the United States through an expensive inspection and eradication program under the oversight of the USDA (Stanford 2002). In 1997 exports to the United States were first allowed to 19 northeastern states in four winter months, and from 1991 to 1998, export volume grew from 13,000 tons to 47,000 tons (Barcenas Ortega and Aguirre Paleo 2005). The ban was gradually lifted, and in November of 2001, permission was granted to export avocados to 31 U.S. states for 6 months of the years. In November of 2004, this was expanded to year-round access to 47 states. Mexican avocados were finally allowed into California, Hawaii, and Florida in 2007 (APEAM 2004). The accompanying rise in production has been dramatic. In 1997, only 1,500 ha of production was exported, or roughly 2% of total production (APEAM 2005). In 2005, production from 32,500 ha was exported, or about 28% of total production, roughly 62% of which went to the United States (APEAM 2006). This suggests that growth in production over the past decade has been driven by exports destined for the United States. This dramatic expansion has led to widespread deforestation in the region and orchard establishment outside the climatic region most suitable to avocado production.

Policy changes: the Reform of Article 27 and the 1992 Forestry Law

We suggest that two policy changes unrelated to avocado production debilitated land governance structures in some communities and led to land use change prior to the intent to establish avocado orchards in former forests. These two policies were the Reform of Article 27 of the Mexican Constitution and 1992 Forestry Law. The Reform of Article 27 (hereafter referred to as the Reform), also enacted in 1992, allowed the titling and sale of commonly owned land under certain conditions. The process involves the intervention of a government program (Program for the Certification of Ejidal Rights – PROCEDE) in which communities can opt to have communal lands measured for individualization. Certificates are then issued for individual parcels, which can be converted to official private property upon approval of a two thirds majority of the communal assembly. While many assumed that the Reform would deal a lethal blow to communal tenure in Mexico (Bray 1996; Goldring 1996; Harvey 1996; Stephen 1998), the effect on forests should have been minimal since, as a protection against deforestation, the Reform stated that forested lands could not be divided. Although division of common lands has occurred (Haenn 2006; Muñoz-Piña, de Janvry, and Sadoulet 2003; Nuitjen 2003; Zepeda 2000) and forest loss has accompanied individualization in certain cases (Barsimantov et al. forthcoming),

the system of communal land tenure in Mexico remains relatively intact and extensive privatization of common lands has only occurred in certain regions. In this paper we trace the illegal land market and resulting deforestation that has ensued in this region of Michoacan since the Reform was enacted in 1992.

The second policy change we explore was the 1992 Forestry Law. One central goal of the 1992 Forestry Law was simplifying the regulatory process in an attempt to improve efficiency in the timber industry. An important part of achieving this goal was reducing the bureaucracy involved in the transport of timber. Prior to 1992, log trucks were required to obtain and carry papers that certified the legality of transported timber. These papers stated the origin, destination, and quantity of timber to be transported within a certain timeframe. While the acquisition of this paperwork was time consuming and therefore an added expense and a disincentive for forest management, it provided a mechanism by which illegal logging could be monitored and enforced. The Forestry Law of 1992 replaced this documentation with the stamp of a special hammer that was used by the forester responsible for the harvest to mark the ends of logs, signifying the legality of transported timber. Widespread abuse of the hammer, along with hammer forgeries, were common immediately following the change in law and led to an high level of illegal logging activity according to multiple interviewees. We explore how this new opportunity for illegal logging, combined with the Reform of Article 27, led to the collapse of local governance. We suggest that were it not for these two changes which undermined local governance, widespread deforestation would have been more limited in spite of the expansion of the avocado industry.

III. RESEARCH DESIGN AND METHODOLOGY

Fieldwork was conducted from January to June, 2006 in four communities in the municipality of Ario de Rosales in the state of Michoacan, Mexico. With the help of a local NGO and government contacts, two communities with active forest management programs and two without active management programs were selected[3]. These communities were also selected to control for exogenous factors that could influence resource management outcomes and confound experimental design, including population size, forest area, topography, and distance to population centers. To attempt to control for forest type, each community was selected to have at least one boundary adjacent to that of another case study community. Table 1 and Figure 1 show general characteristics of case study communities and their locations. As shown in these graphics, three are roughly the same size, whereas one of the communities without a management plan is considerably larger. Both communities with forest

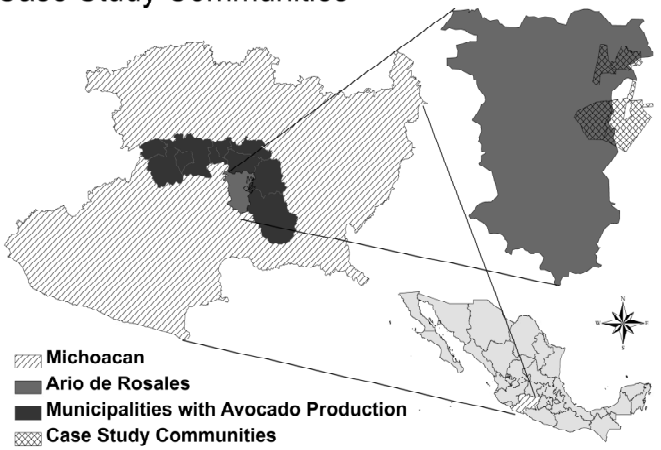
[3] After site selection and initiation of the study, we discovered that one of the communities categorized as without a forest management plan actually has a plan registered with the Environmental Ministry. However, the plan pertains only to forest parcels of 6 of the 72 community members. Due to the minimal surface area (less than 10% of forest area) implicated and the fact that decisions about forest management are made, in this case, on an individual rather than a communal level, we continued to classify this community as without a community forest management plan.

management plans are slightly closer to paved roads and are slightly less steep, however these differences are minimal.

Table 1: Characteristics of Case Study Communities[4]

	Active Forestry Program	Annual Permitted Volume (m3)[5]	Total Surface Area (ha)[6]	1990 Forested Surface Area (ha)[7]	Distance to Paved Road[5]	Total Population[8]	Topographic Roughness[9]
Las Lomas	Yes	970	1116	319	0.1 km	794	1.015
San Juan	Yes	2100	971	286	1 km	748	1.027
El Cajoncito	No	0	946	441	4 km	537	1.030
Las Palmas	No	0	3329	1598	7 km	710	1.033

Figure 2: Location of Study Region and Case Study Communities



In each community, a household survey was applied in a 20% random sample of households, resulting in a total of 127 surveys. Surveys were comprised of 87 close-ended questions on household demography, income and employment sources, agricultural production, community participation, and use of common resources. Surveys were applied in person by Mexican undergraduate university students and had a 94% response rate. In addition, roughly 10 open-ended interviews using a snowball sampling technique were applied in each community, focusing on local elected officials, key informants with ample knowledge of forest use, and older members with historical knowledge of the community. Questions pertained to the following areas: history of forest use, structure and function of local government, rules for resource use, and interaction with external actors. Finally, to understand effects of policy changes on the

[4] Community names have been changed to pseudonyms
[5] Data obtained from the Secretariat of the Environment (SEMARNAT) in each state.
[6] Calculated using GIS, shapefiles of community outlines
[7] Calculated using Landsat TM images, see methodology below
[8] Data obtained from 2005 Population Count (National Institute of Statistics, Geography and Information - INEGI)
[9] This is a measure of rugosity created using SRTM digital elevation models and the ArcView plugin Benthic Terrain Modeler. Rugosity, as defined here, is the mean of each cell's ratio between the surface area and planar area, averaged over the community. Values from 1-5 are given to each cell, from 1=flat to 5=steep. For more information see (http://www.csc.noaa.gov/products/btm/).

communities, twenty interviews were conducted with government officials (8 interviews), NGO staff (5 interviews), private foresters (4 interviews), and timber companies (3 interviews). Interviews were also open-ended, focusing on interviewees' knowledge of case study communities, their interactions in general with forest communities, and their understanding and opinions about forest management in the state.

An analysis of land cover change was also conducted in which the extent of change was determined in 11 municipalities that comprise the vast majority of the avocado production region of Michoacan. Land cover change statistics were also determined for case study communities. This portion of the study was conducted using Landsat TM and ETM images from 1990, 1996, 2002 and 2006[10] using post-classification techniques and the ENVI software package. Dates of images were selected to measure deforestation before trade negotiations opened avocado export markets to the united but after the Reform of Article 27 and the 1992 Forestry Law (1990-1996), as rapid expansion was occurring due to changes in trade negotiations (1996-2002), and as land available for expansion became more limited (2002-2006). In this way, we hoped to determine how policies other than changes in avocado trade rules affected deforestation. Since we hypothesize that the Reform of Article 27 and the Forestry Law of 1992 induced deforestation, we expect to see high deforestation beginning in the 1990-1996 period. On the other hand, if deforestation was due primarily to changes in avocado export rules, we should not see the spike occur until the 1996-2002 period.

The analysis was conducted using a maximum likelihood supervised classification tool using three vegetation classes: forest, nonforest, and orchards. Categories of water and volcanic rock were also used to exclude these areas from analysis. For the purposes of this analysis, we define the avocado production region in a slightly smaller elevation zone (1200-2500 meters above sea level, as compared to 1050-2600m) due to the fact that production in the highest and lowest elevations is difficult and less than 0.2% of orchards are found below 1200 and above 2500 meters above sea level. Cloud cover in all images except the 2006 image was 0%. Minimal cloud cover (<3%) was found in the 2006 image. Since all patches of cloud cover occurred over large patches of land cover that had remained stable during the first three images and surrounding areas in the 2006 image has also remained stable, these small areas were manually corrected. Due to a failure of the Scan Line Corrector (SLC) in the Landsat 7 satellite in 2003, all images taken after 2003 have gaps of striping across the image, covering roughly 10% of the image. To fill these gaps, three images taken on similar dates either in the same year or in adjacent years were selected and used by the USGS to produce a gap-filled image. While this process clearly distorts spectral values, valid land cover classification can still be performed (Tappen and Kushing 2004), and the use of images for gap-filling from similar months and adjacent years makes it likely that error from the SLC image

[10] All images were row 28, path 47. Image dates: 3/16/1990, 4/1/1996, 3/9/2002, 4/5/2006

is minimal. Due to the spectral similarity of mature avocado orchards and riparian, broadleaf forest, there was some misclassification of these groups. However, the spatial nature of these patches (namely, riparian forests in long strips and orchards in polygons with straight edges) made it easy to manually correct these errors. Post classification techniques were used to compare forest cover in the four images to produce a final calculation of forest cover change. To test accuracy of classifications, 350 GPS groundtruthing points were collected in the field. Overall accuracy was between 96.5% and 98.8%, and the kappa coefficient was between 0.88 and 0.93 for all classifications.

A multi-case comparative approach, using careful selection of communities and combining qualitative and quantitative data, can allow for a strong level of causal inference in social research that may not be possible using single case studies or a disciplinary focus (King, Keohane, and Verba 1994). In addition, the use of qualitative information can help explain reasons behind observed process, which purely quantitative studies often cannot achieve (Tarrow 1995). This type of research on land use and cover change is crucial in understanding human-environment interactions while bridging the natural and social sciences (Turner et al. 2001).

IV. RESULTS AND DISCUSSION

Land cover change at the regional level

Results of the land cover change analysis in 11 municipalities that produce avocados[11] show that over 33.1% of forest cover, or 48,600 ha of 146,700 ha, has been lost between 1990 and 2006 in elevations above 1200m. This represents a 2.5% annual rate of change, much higher than the 1% rate of change calculated by Velazquez et al. (Velazquez et al. 2002) for highland forests across the country. Results are even starker when these results are limited to elevations suitable for avocado production. In elevations between 1200 and 2500m above sea level, the zone suitable for avocado production, 39.5% of forest has been lost, corresponding to an annual deforestation rate of 3.1%. In elevations above 2500m, only 13% of forest has been lost, corresponding to a 0.9% rate of deforestation, which is very close to the national average for forest loss in highland forests according to Velazquez. Elevations below 1200m are outside the scope of the study because ecosystems types change and therefore land cover classifications would need to be modified.

At first glance, this general view of land use change might suggest that the growth in production of avocados has led to deforestation and is the result of simple utility maximizing on the part of farmers in the region. Because profits from avocado production far exceed those of other land uses in the region, an obvious incentive to deforest exists. While this explanation may be correct in general, it cannot explain two important characteristics of land use change in the

[11] These 11 municipalities produce over 95% of avocados grown in Michoacan

region that, when properly understood, may provide strategies to reduce deforestation in the region. First, it does not explain why some communities choose to deforest while others with similar geographic characteristics do not; it ignores local governance. This point will be explored in the following sections as case study communities are analyzed. Second, it cannot explain the trajectory of events that permitted the violation of forestry and agrarian laws and led to high levels of land cover change well before the rapid increase in avocado production.

A closer look at deforestation rates by municipality and time period show how important this second feature is in understanding the trajectory of forest loss. Most notably, while the deforestation rate remained relatively constant across the entire study region in the three time periods, in Ario there was little deforestation between 1996 and 2002 and most deforestation occurred in the first and third time periods. The first time period corresponds to the period in which the Reform of Article 27 and the 1992 Forestry Law were passed but the boom in avocado production had not yet occurred. The high level of deforestation in this time period in the municipality of Ario suggests that these two policy changes may have led to high levels of deforestation. Since avocados production was not yet increasing, we can conclude that deforestation in these years was unrelated to avocado production and rather was catalyzed by individualization of common lands and liberalization of timber transport laws. Low levels of deforestation in the subsequent period, in the early years of the avocado boom, suggest that there was sufficient land cleared of forest to satisfy demand for land for new orchards. Finally, when export markets opened and avocado production expanded rapidly around 2002, new land needed to be deforested in order to satisfy demand for orchard land. The pattern of results found in Ario will be closely inspected in the next section at the level of the community. The fact that this pattern does not hold across the 11 municipalities suggests that this result may not be generalizable to the entire region and that other factors may have influenced the pace the timing for forest loss in addition to the policy changes mentioned above. Table 2 summarizes these findings:

Table 2: Land Cover Change in Avocado Region and Municipality of Ario

	1990-1996	1996-2002	2002-2006	Overall (1990-2006)
11 Municipalities				
Percent Change	-13.84%	-13.10%	-10.71%	*-33.15%*
Deforestation Rate	-2.45%	-2.31%	-2.79%	*-2.49%*
Ario				
Percent Change	-27.38%	0.11%	-22.41%	*-43.59%*
Deforestation Rate	-5.19%	0.02%	-6.15%	*-3.51%*

Land cover change in case study communities

Of the four case study communities, two have an active community forestry program while the other two do not. All four of the communities are relatively small, between 32 and 82 members, with one possessing a considerably larger surface area. Dirt roads to all case study communities divert

from the same paved road. Results of the land use change analysis in these four communities in detailed in Table 3 below, and it is clear from these figures that deforestation has varied enormously between the two pairs of communities.

Table 3: Land Cover Change in Case Study Communities

	Forest Area 1990	1990-1996	1996-2002	2002-2006	Overall (1990-2006)
Las Lomas	319				
Hectares of Change		-41	+11	-29	-91
Percent Change		*-12.8%*	*3.6%*	*-9.6%*	*-15.0%*
Deforestation Rate		**-2.3%**	**0.6%**	**-2.5%**	**-1.0%**
San Juan	286				
Hectares of Change		-5	+11	-26	-21
Percent Change		*-1.9%*	*4.0%*	*-9.0%*	*-7.2%*
Deforestation Rate		**-0.3%**	**0.7%**	**-2.3%**	**-0.5%**
El Cajoncito	441				
Hectares of Change		-338	-24	-20	-381
Percent Change		*-76.6%*	*-23.2%*	*-24.8%*	*-86.5%*
Deforestation Rate		**-21.5%**	**-4.3%**	**-6.9%**	**-11.8%**
Las Palmas	1598				
Hectares of Change		-1030	-415	-32	-1477
Percent Change		*-64.4%*	*-73.0%*	*-20.9%*	*-92.4%*
Deforestation Rate		**-15.8%**	**-19.6%**	**-5.7%**	**-14.9%**

In the two communities without active forest management plans, over 85% of forest has been lost between 1990 and 2006. Most of this land area, according to community members, is legally designated as commonly owned but has been sold illegally to outsiders by individuals. In the two communities with forest management plans, the extent of forest loss has been much less, and only small patches of land have been sold to outsiders. In addition, most land cover change in Las Lomas was due to bark beetle infestation that resulted in the removal all forest cover in certain areas.

Before discussing the history and process of land cover change in each pair of communities, it is important to exclude certain geographic factors that might have influenced these processes. Deforested areas in each community were not those with better access, as is suggested in many studies of deforestation (Kaimowitz and Angelsen 1998) . Visual interpretation of imagery and digital elevation models suggests that deforested areas in the two non-forestry communities were those with the greatest inclination, while forested areas in flatter areas in the other two communities were not deforested. In addition, ease in road access did not play the role frequently suggested in the literature: Forests in communities with low deforestation have better access roads than the two with high deforestation, principally because they are not as steep. This suggests that non-geographic factors played a preponderant role in land cover change.

The history of forest use since 1990 within each pair of communities is quite similar, and thus results will be presented in pairs. Both communities with

no active management plan had forest management plans prior to 1990. However, in both communities participation by locals was minimal; private foresters and local timber companies conducted the vast majority of activities related to timber harvesting and the communities were severely undercompensated for their timber. Productive activities of locals in communal forest consisted of the collection of tree resin and firewood harvesting. Each community member possessed individual usufruct rights to an area of forest, termed *cuarteles*, for the extraction of resin. These use rights, however, did not include rights to the timber or the land in these *cuarteles*, as is evidenced by the fact that the size of individual *cuarteles* was determined based on the amount of resin potentially available rather than on surface area. In addition, *cuarteles* were only transferable to other member or non-member residents as an entire membership package; sale to outsiders or in individual parcels was not allowed. Community members could not remember the exact year in which their forest management plans was discontinued, and unfortunately these data were not available from SEMARNAT. Nevertheless, both communities, as well as two other nearby communities that were visited during fieldwork, described a similar chain of events. The Reform of Article 27 and the Forestry Law of 1992 were both key points in the process by which community members obtains individual rights over timber and land in their *cuarteles*.

Both communities described visits by people from outside the community, presumably government officials, who misinformed residents by telling them that, as a result of the Reform of Aricle 27, communal lands were no longer technically government property and thus could be divided into individual parcels. It is important to note that these visitors did not initiate the official process of certification of communal lands under the PROCEDE program, which did not occur until several years later. In this official process, rules stating that forested lands cannot be divided are explained and usually enforced. This misinterpretation of the Reform, combined with the Forestry Law of 1992, initiated a wave of illegal logging in these communities and in others in the region. Both communities decided that members henceforth had the right to harvest timber in their *cuarteles*, where previously they only had rights to extract resin. From this point onward, the communal assembly met less frequently and with fewer members attending. Previously, interviewees remember monthly meetings with high levels of participation. The Forestry Law of 1992 required that logs were marked with a special hammer to legalize transport instead of paper documentation that specified the origin, destination, and permit information of timber. This hammer was easy to replicate and its use was often not well guarded, and in this manner community members faced little difficulty in illegally harvesting and transporting timber to saw mills. Local informants and government functionaries reported that between 1992 and 1995 between 30 and 40 log trucks brought timber out of these two communities on a daily basis. In a few years, the majority of timber had been harvested. Payment for timber was extremely low; one interviewee estimated that members sold timber for the

current equivalent of 30 pesos a cubic meter. The current value of timber fluctuates around 700 pesos per cubic meter.

It was clear among both local informants and external actors that the intention of illegal logging in the years immediately after 1992 was not eventual sale of land or establishment of avocado orchards. This coincides both with results of the land use change analysis described above and the fact that intensive orchards expansion did not occur in these communities until at least 2000. Only several years after forests had been illegally logged did outsiders from larger population centers buy land with the intention of planting avocados. As communal forests no longer had standing timber value, it was a natural step for members to extend their usufruct rights to individual ownership of land. In fact, it may have been and may still be difficult to sell land with standing pine trees because government regulation of illegal logging has become much stricter in recent years. The *cuartel* of one community member burned in a forest fire several years prior to the rush of land sales. Because his land had dense regrowth of pine trees, he did not sell his land. Thus, at least in some cases, illegal logging may be a necessary precursor to illegal land sales and conversion to orchards.

According to interviewees, members in both communities have sold between 50% and 75% of all land in the community, which corresponds to a much higher percentage of all common land. Most sold land at the equivalent of between $500 US and $1,000 US per hectare, and all of these sales were illegal due to the simple fact that forested land cannot be sold under the Reform of Article 27, not to mention that the official certification and titling process had not been conducted prior to land sales. The new owners subsequently cut down remaining vegetation that had no timber value, including oaks and shrubs, in order to plant orchards. Currently, nearly all orchards in areas that were previously forested belong to outsiders, while community members have begun planting their own orchards in agricultural fields that they still own. In many cases, members or their children have become day laborers on land they formerly owned. The current price of land without an avocado orchard is roughly $10,000 per hectare, or 20 times more than the price at which most land sold roughly 5 years earlier. At the time of fieldwork, assemblies in each community met only when necessary, which may be as little as once a year, and usually only to elect new local authorities or when government officials arrive to offer agricultural subsidies.

The two forestry communities show a very different history of forest use. In 1990 neither community had a forest management program and timber was harvested principally for domestic consumption with small quantities sold illegally. Usufruct rights to resin were distributed in a similar fashion to the other two communities. Local informants reported no effects of the Reform of Article 27 or the Forestry Law of 1992 on quantities of timber extracted, privatization of communal land, or timber rights. Frequency of and participation in assemblies

has stayed about the same since 1990, with meetings occurring between every month to every three months and the majority of members attending. In 1997 in one community and in 2002 in the other, forest management plans were initiated. In one of the communities, a few members began to expand their agricultural plots into the adjacent communal forest and some deforestation occurred. More forest would have been lost if not for the implementation of the forest management plan which provided a stronger governance framework to control members that preferred to deforest. In the second community, certain members began claiming individual rights to common land. However, because the majority of the community wanted to maintain commonly owned forests, this was not allowed and rule-breaking members were forced to relinquish their encroachment into the common forest. In one of the communities, a communal avocado orchard was initiated and profits are used for community projects. Recently this income has been used to pave the steep road that enters the community. In the other community, a community land use plan was completed with the help of a local NGO, and one of the principal results has been limiting pressure on forest resources through more active local governance. In both communities, a minority of members would prefer to divide forested land with the intention of selling it to avocado producers. However this minority cannot disregard community rules because the assembly is still functioning and well-respected.

Comparison of socioeconomic factors in study communities

What differences are evident between the two pairs of communities and how can these differences provide an understanding of why such different forest use patterns occurred? Tables 3-5 compares the means of various socioeconomic indicators obtained in household surveys and a discussion of these results follows.

Table 3: Results of Geographic and Selected Socioeconomic Factors

	% of households that own a refrigerator	average distance to paved road	average education of heads of households and spouses[12]	average education level of all family members between 12 and 24 years of age[6]
Non-Forestry Communities	27%	5 km	1.8	3.2
Forestry Communities	55%	0.5 km	2.6	3.7

Table 5: Percent responding that each income category was “important” or “very important” to total household income

	Agricultural Products	Day Labor	Work Outside the Community	Remittances	Government Agricultural Subsidies (PROCAMPO)
Non-Forestry Communities	53%	47%	2%	13%	27%
Forestry Communities	55%	25%	20%	15%	11%

[12] Highest level of education obtained: 1=none, 2=did not complete primary school, 3=completed primary school, 4=completed middle school, 5=completed high school, 6=completed post-high school education.

Table 4: Resources Use and Governance (all in a Likard scale of 1 a 5)

	Non-Forestry Communities	Forestry Communities
Do you use more gas (1) or firewood (5) for cooking?	4.6	3.3
Do you collect (1) or buy (5) most of your firewood?	1.2	2
Do you ask permission to collect firewood? (1-never - 5-always)	1.2	2
Do you inform authorities when you see someone breaking rules? (1-never, 5-always)	2.8	3.8
Whom do you usually inform? (1-assembly – 5-government authorities)	2.2	1
How has the strength of the community changed in the last 10 years? (1-weaker - 5-stronger)	2.2	3.4
How has participation in community work days changed in the last ten years? (1-less participation - 5-more)	2.5	3.5

These results suggest that forestry communities have more wealth, are better educated, depend less on firewood for fuel needs, and have better road access. Interestingly, these findings also suggest that the gap in education between the communities is less among the younger generation, probably due to better access to secondary schools and greater importance placed on education in the younger generation. In addition, there is a stark difference in income sources between the two pairs of communities: the forestry communities have more work opportunities outside the community, presumably in the municipal seat, while the non-forestry communities depend more on day labor in avocado orchards. The non-deforested communities also have stronger local governance structures including stronger rules and better local mechanisms to enforce rules, and in addition have strengthened their local governance over the past 10 years.

V. CONCLUSIONS

It seems evident that structural differences in local governance are a key factor that has the potential to limit individualization of communal land and subsequent deforestation. First, it is clear that communities that have not extensively deforested have a local governance structure that is stronger than that of deforested communities. In addition, the internal governance of the deforested communities suffered a collapse in the early 1990s. This is an indicator that the resilience of internal governance to policy changes may be a determinant of their ability to manage natural resources.

To explain why some communities are more resilient than others is a difficult task, and we thus propose a set of potential explanations. First, better access roads, higher education levels, more income generation outside the community, and less dependence on firewood (as a proxy for the necessity to exploit forest resources) are evident in the non-deforested communities. This suggests that people in better economic conditions have less need to degrade their natural resources, or at least have longer time horizons. With a lower internal discount rate, they are not in as dire need for quick income as similar communities that are slightly less well off, and can therefore chose land use options that may be more beneficial over the long term by maintaining ecosystem

services and a small income stream from the sale of timber. To generalize this conclusion, a controlled study with a larger sample size would be necessary.

As an alternative or additional explanation, we suggest that the marked difference in history of forest management could have affected the events that took place in the early 1990s. On the one hand, the non-forestry communities, both of which had forest management plans prior to 1990, had an understanding of the value of timber through their experiences. In addition, they had little control over the management of forests in their communal lands and by all accounts probably received unfair monetary compensation for their timber. Thus the policy changes of 1992 might have given them the opportunity to take control of a resource that they knew was valuable but previously had little to benefit from. On the other hand, given that the forestry communities did not have systematic experience of economic benefit from timber harvests, the policy changes of 1992 may not have created the same release of individual control that was displayed in the other two communities. The opportunity for greater participation and fairness in timber sales when these communities initiated their forestry programs may have created an incentive to maintain forestry programs even when more lucrative options exist. A combination of these two sets of explanation may adequately describe the reasons why one pair of communities decided to deforest while the other did not.

Regardless of the certainty of these explanations, the sharp contrast in the level of land use change between the two pairs of communities and the importance of the strength of internal government to manage forest resources is evident. In addition, the effect of policy changes initiated in 1992 on the governing structure of communities is clear. This is confirmed by the relatively low levels of land cover change in Ario between 1996 and 2000, which signifies a pause in deforestation between the period of intensive illegal logging and the sale of communal lands for avocado production. This was shown both with calculations of land use change in different time periods as well as in multiple interviews with informants both inside and outside the communities. Thus, the role of these policies in facilitating the weakening of internal governance of communities is evident.

We conclude by noting that if deforestation was facilitated by policy changes in land tenure, forestry, and trade, there is no doubt that the path to reducing deforestation rates will require the integration, participation, and co-responsibility of these three sectors, particularly with respect to strengthening local governance structures.

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