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Integrating analyses of local land-use regulations, cultural perceptions and land-use/land cover data for assessing the success of community-based conservation

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Abstract

Studies of land-use/land cover change are an important means for examining the viability of community-based programs for forest conservation, although an analysis of the social processes influencing land-use decisions is necessary to understand the factors leading to different conservation outcomes.

In this paper, we demonstrate that an analysis of locally recognized land-use rules and regulations embedded in local institutions can inform remote-sensing approaches by helping: (1) to elucidate some of the local perceptions, criteria and interactions with outside agencies that drive conservation actions and (2) to better interpret the spatial patterns of land-use change and forest conservation revealed by remote-sensing data.

Based on a case study of a forest ejido from the Maya Zone of Quintana Roo, Mexico, we evaluate changes in forest cover and in local land-use regulations before and after the initiation in the mid-1980s of a community forestry program, the Plan Piloto Forestal (PPF). Methods included development of a time series of land cover maps based on LANDSAT imagery from 1976, 1988, 1991, 1997 and 2000, as well as interviews and participant observation with local farmers and community leaders.

Results indicate a high degree of forest conservation on community lands with net rates of forest loss of 0.6–0.7%/year. Locally recognized conservation regulations included a number of forest reserves as well as regulations which protect specific forest types, resulting from both local initiatives and interventions of external agencies. These initiatives included but were not limited to the PPF, highlighting the importance of evaluating community-based conservation programs within a broader historical context. Conservation regulations protecting an important commercial non-timber forest product (*Manilkara zapota*) pre-dated the PPF and may have facilitated its implementation. In the most accessible agricultural areas, the only mature forest patches were customary forest reserves and an area regenerated from secondary forests, protected due to enrichment plantings of commercial timbers. Recognition of local Maya terminology used to distinguish forest types was crucial for proper interpretation of local land-use regulations, which revealed that less-valued forest types may not be adequately protected on community lands.

We suggest that future research should examine the significance of the less-valued forest types for global biodiversity conservation. In addition careful consideration of the historical antecedents and community institutions which may have facilitated the implementation of the Plan Piloto Forestal will be important for the successful application of this model of community forestry to other socio-economic and cultural contexts.

Keywords: Common property institutions; Land-use/land cover change (LUCC); Yucatec Maya; Community forestry; Plan Piloto Forestal; Folk classification; Quintana Roo; Mexico

1. Introduction

Forest conservation efforts increasingly have sought the collaboration or involvement of local communities through various incentives and programs that encourage forest-based economic activities (Klooster and Masera, 2000; Salafsky et al.,

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2001; Al-Sayed and Al-Langawi, 2003; Plummer and FitzGibbon, 2004). One objective way to evaluate the long-term effectiveness of community-based conservation initiatives is by measuring changes in forest cover after their implementation using remote-sensing data. While in some cases continued degradation of community forests has been reported (Semwal et al., 2004), a number of studies has also revealed improvement or maintenance of forest cover in areas with formal community forestry or integrated development and conservation programs (Jackson et al., 1998; Smith, 2003; Bray et al., 2004; Gautam et al., 2002). In some cases, rates of forest conservation in community forests have been found to be higher than those in protected areas or government forests (Browder, 2002; Duran et al., 2003; Gautam et al., 2004).

Remote-sensing data provide useful spatial information to assess forest cover changes, but an analysis of the social processes influencing land-use decisions is necessary to understand the factors leading to different conservation outcomes (Mascia et al., 2003). On common property lands, land-use practices and the management of natural resources are often regulated at the community-level by a series of rules, regulations and norms or traditions (Ostrom, 1990; Berkes, 1999; Howard and Nabanoga, in press). These local institutions are influenced by the worldview, cultural perceptions and knowledge systems of local actors, as well as in cross-scale interactions with other political entities (e.g. governments, non-governmental organizations, other communities) (Berkes, 1999, 2002).

In this paper, we present a case study from the ‘‘Maya zone’’ of Quintana Roo, Mexico to demonstrate that an analysis of locally recognized land-use rules and regulations embedded in local institutions can inform remote-sensing evaluations of community-based conservation programs by helping: (1) to elucidate some of the local perceptions, criteria and interactions with outside agencies that drive conservation actions and (2) to better interpret the spatial patterns of land-use change revealed by remote-sensing data. Since the mid-1980s Maya communities in central Quintana Roo have participated in a state-wide community forestry program called the ‘‘Plan Piloto Forestal’’ (PPF) (Kiernan and Freese, 1997; Flachsenberg and Galletti, 1998; Merino Pérez, 1997, 2004). Regional land-use/land cover studies in Central Quintana Roo have revealed some of the lowest rates of forest loss in Mexico (Bray et al., 2004; Duran et al., 2003). Here, using remote-sensing data (1976–2000) and a historical reconstruction of local land-use regulations we show that high rates of forest conservation are the result of a combination of both local initiatives and interventions of external agencies—including but not limited to the PPF, and furthermore that these conservation actions are highly influenced by the Maya perception of local forest types.

2. Study area

2.1. Location and population

The study was carried out in the Ejido X-Maben (hereafter referred to as ‘‘X-Maben’’). X-Maben is located in the Central part of Quintana Roo (Fig. 1), in a region locally referred to as the ‘‘Maya zone’’. In Mexico, the ejido is a form of collective land tenure whereby the government grants usufruct land-use rights to a group of members, or ejidatarios. X-Maben measures over 730 km^2, and spans two paved highways leading from the nearby town of Felipe Carrillo Puerto to the cities of Valladolid and Cancun. The X-Maben land-grant was petitioned in the 1930s, and the grant was formalized in 1955.

The population is almost entirely Yucatec Maya, most of whom are descendents of the Maya rebels who fought against government forces in the Caste War (1850–1901) (Reed, 1964). The oldest villages in the region are thought to have been settled near the end of the war, although the region was inhabited throughout the war, serving as a refuge for the rebels (Sullivan, 1987; Hostettler, 1996, pp. 47–58).

In 2000, X-Maben had an estimated population of approximately 2849 (average population density 4 people/km^2) (INEGI, 2000), approximately 83% of which is concentrated in the largest village, Señor, located along the

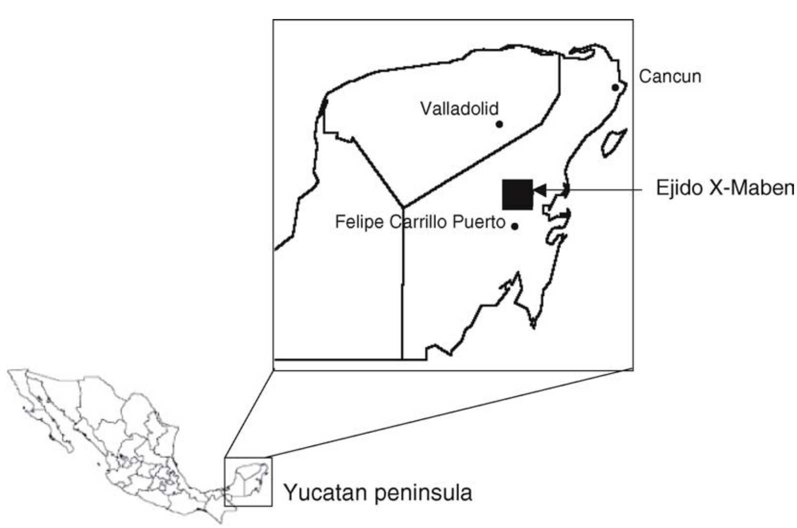

Fig. 1. Locational map of study area (Ejido X-Maben).

highway to Valladolid. From 1970 to 2000, the population of Señor increased by a factor of 2.5, from 939 to 2362 people (Secretaría de Industría y Comercio, 1971; INEGI, 2000). Nine other permanently inhabited settlements had populations of less than 200 people in 2000 (Fig. 2a); since 1970 most of these settlements either remained stable or declined in population. In addition, a number of ''ranchos'' which are only temporarily inhabited are scattered around the ejido and are used as a base for agricultural or animal husbandry activities. The locations and names of a total of 79 ranchos and abandoned villages were recorded during the field study (Fig. 2a).

2.2. Physical environment

Geologically, Quintana Roo is part of a limestone platform which constitutes the Yucatan peninsula (Fig. 1). The karstic environment is characterized by thin, limestone-derived soils (mostly lithosols and rendzinas in X-Maben), and a system of

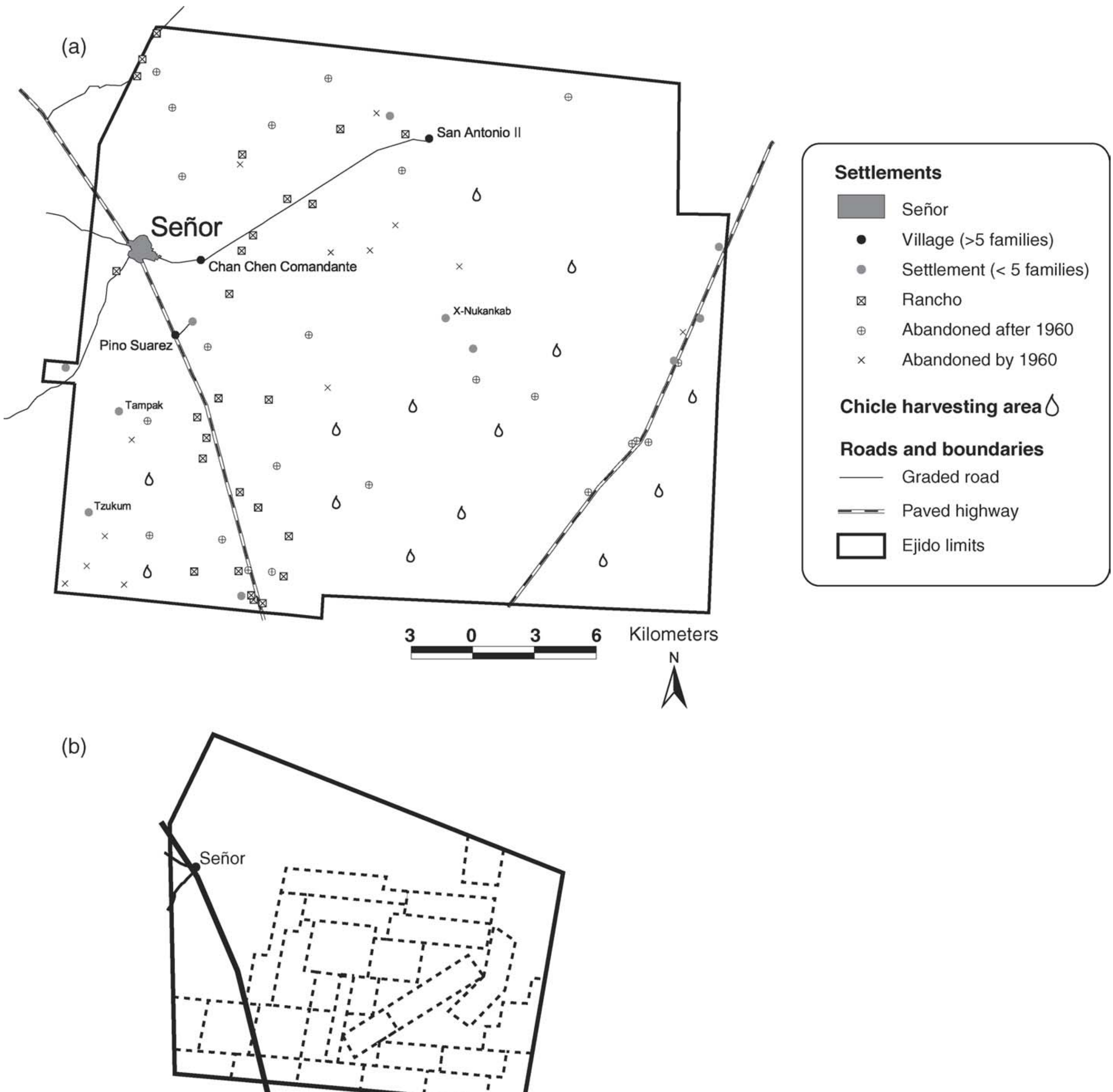

Fig. 2. Maps of: (a) settlement patterns and chicle harvesting areas and (b) the permanent forest area (PFA). (a) Villages and settlements are distinguished by the number of families observed to be there on a permanent basis in 2002–2003. Ranchos are inhabited only temporarily and used as a base for agricultural or livestock production. (b) The PFA is indicated by dotted lines which show the location of rotation blocks from the 25-year management plan for timber harvesting. This map was adapted from the ''Plano Plan de Corta, Ejido X-Maben y Anexos'', OEPFZM, 2001.

underground drainage systems and sinkholes (Flores and Espejel Carvajal, 1994). In X-Maben, average annual temperatures are approximately 26 °C, while average annual precipitation ranges from 1200 to 1500 mm/year (Instituto de Geografía, 1990), with a marked dry season occurring from January to April.

The vegetation in X-Maben is generally described as medium semi-deciduous tropical forest (*selva mediana subperrenifolia*) in the Mexican classification system, with a maximum stature of approximately 15 m. Approximately 25% of the foliage is shed in the dry season, and forests are dominated by the canopy species *Brosimum alicastrum* Swartz and *Manilkara zapota* (L.) Van Royen (Flores and Espejel Carvajal, 1994; Pennington and Sarukhán, 1998). Several inundated vegetation types are found in small extensions, on gley soils particularly in the eastern part of the ejido. In the local Maya classification of forest types, three main types of upland vegetation are recognized: **yáax k'áax**, **k'an lu'um k'áax** and **laaj kaj**. These are identified mostly by their species composition, although they also differ in stature and phenology (Table 1).

2.3. Land-use and economic history

The principal and most longstanding land-use practice in the Maya Zone of Quintana Roo is a traditional system of shifting cultivation (or swidden-fallow agriculture) known as the ''milpa'', which is based on a polyculture of maize, beans and squash. Most families also produce small livestock and a variety of edible and medicinal plants in homegardens, while hunting and the gathering of a variety of wild plant resources are practiced in milpa, fallows and forests.

Since the early 20th century one of the main sources of cash income for Maya communities in Quintana Roo has been the sale of ''chicle'' (Villa Rojas, 1992; Hostettler, 1996), the latex of one of the dominant forest species, *Manilkara zapota*, which is used as the basis of natural chewing gum. The international chicle market underwent a boom in the 1920–1940s during which time Quintana Roo was the principal producer. Since then, the market has declined; however, some Maya households in X-Maben still participate to some degree in chicle tapping.

Table 1
Main vegetation types recognized in the local Maya classification in X-Maben

Vegetation type	Characteristics
Yáax k'áax	Forest rich in a number of economic and useful species such as *Swietenia macrophylla* King, *Manilkara zapota* (L.) v. Royen, *Sabal yapa* C. H. Wright ex Becc., *Brosimum alicastrum* Swartz. Generally taller than **k'an lu'um k'áax**, and less deciduous. Translates as ''green forest''
K'an lu'um k'áax	Forest with many spiny plants, deciduous in the dry season, such as *Acacia pennatula* (Schldt. and Cham.) Benth., *Pithecellobium albicans* (Kunth.) Benth., *Mimosa bahamensis* Benth., and *Lysiloma latisiliquum* (L.) Benth. Translates as ''forest of yellow/orange soils''
Laaj kaj	Vegetation type associated with Mayan ruins. Literally translates as ''old village''. High density of the cohune palm (*Attalea cohune* Mart.), and several other characteristic species, including many vines. Often deep organic black soils. Highly appreciated for milpa agriculture and nearly always occurring in early stages of succession

Since the early 1970s, construction of roads and greater integration into national life have opened up new economic opportunities, including small scale commercial activities, wage labour, and sale of handicrafts, honey, and horticultural products (Sullivan, 1987; Hostettler, 1996). X-Maben has participated in the PPF since 1986, forming part of a second-level organization called the *Organización de Ejidos Productores Forestales de la Zona Maya* (OEPFZM), which provides technical support in the development of management plans and the commercialization of the forest products. Community forestry activities in X-Maben have focused on the extraction of precious timbers (mahogany and Spanish cedar) and on the production of railroad ties derived from tropical hardwoods (Merino Pérez, 1997).

3. Methods

The methodology included interviews and participant observation to document forest conservation regulations, while participatory mapping, the development of a time series of land cover maps and spatial analyses served to quantify spatial and temporal patterns of land cover change.

3.1. Interviews on land-use regulations

Forest conservation regulations in X-Maben were documented in two ways. First, familiarity with land-use practices was gained through participant observation and informal discussions with various men and women during 12 months (between June 2002 and April 2004) of field work and residence in the main village Señor by the first author (SPD). During this period a conversational fluency in Yucatec Maya was attained and the main elements of land-use practices and regulations were identified. Second, in order to establish the chronological sequence of land-use agreements, semi-structured interviews were conducted with 10 of the men who served as presidents of the ejido assembly from 1967 to 2004. Ejido presidents each serve a 3-year term and preside over all assembly meetings where collective decisions are made. All internal complaints or denouncements about land-use are fielded by the ejido president, who also serves as the primary interface between the ejido and government or other external agencies. The interviews with the past ejido presidents therefore permitted the development of a historical perspective of the land-use regulations and interactions with outside organizations.

Interviews were carried out with the help of a local assistant in either Maya or Spanish, though Maya terms were always used for discussing forest types. Each president was asked about land-use regulations and how they were introduced (through internal initiative or via external interventions), milpa practices and community-level projects which existed during

Table 2
Characteristics of satellite images used and results (root mean square, rms) from the georeferencing operation (1st degree polynomial method with nearest neighbour resampling)

Date	Sensor	Pixel size (m)	No. bands used	rms	No. points for rms
February 12, 1976	Landsat 2-MSS	60 × 60	3	0.536	19
December 16, 1988	Landsat 4-TM	25 × 25	5	0.501	29
February 16, 1991	Landsat 5-TM	25 × 25	5	0.478	23
January 31, 1997	Landsat 5-TM	25 × 25	5	0.518	12
February 9, 2000	Landsat 5-TM	25 × 25	5	0.489	14

his 3-year term. In addition, we asked the president to recall all accusations of land-use infractions which he fielded and how they were resolved. A synthesis of the land-use regulations was developed by comparing interviews among the 10 presidents. This synthesis was further supplemented and verified with information from field observations and informal discussions with other community members conducted during the course of the 12 months spent in the field. These were generally consistent with information collected in interviews with the ejido presidents.

3.2. Participatory mapping

A series of participatory mapping exercises were carried out in October and November 2002 in order to identify the location of settlement and ranches, chicle harvesting areas, and forest reserves. Three workshops with 8–10 participants were held in which the approximate locations of these elements were identified on a base map derived from digital orthophotos obtained from the Instituto Nacional de Estadística Geografía e Información (INEGI—Aguascalientes, Mexico). Coordinates for all settlements and ranchos were then obtained with a GPS in the field with the help of a person familiar with each site, and approximate dates of occupation were recorded. Due to their remoteness, most chicle harvesting areas were estimated from the base map only.

3.3. Land cover maps

To examine changes in forest and agriculture land covers in X-Maben, a time series of land cover maps (including milpa, fallows and forest land covers) were developed based on Landsat satellite images from 1976, 1988, 1997 and 2000 (Table 2). In addition, a map of the location of milpas only was developed for 1991 (Table 2).

3.3.1. Image processing

All image processing was carried out with the program ENVI Version 3.5 (Research Systems Inc., Boulder, CO, USA). The images were all georeferenced with respect to a Landsat7-ETM image from April 21, 2000 with a 30 m pixel × 30 m pixel size,[1] achieving a root mean square of near 0.5 pixels (Table 2).

[1] This last image had been georeferenced using topographic maps in the context of the 2000 National Forest Inventory of Mexico.

The 1976, 1988, 1997 and 2000 images were classified using a supervised maximum likelihood algorithm. Training sites were identified using an unsupervised classification (ISODATA method in ENVI) of each image, in which spectrally homogeneous groups of pixels could be identified. A separate set of training sites was identified for each image. Interpretation of the land covers/land-uses associated to each of these training sites was made by comparing the unsupervised classification to several data sources. These included: (1) 468 GPS points taken in different vegetation types in X-Maben between June and December 2002, (2) a series of six colour aerial photographs taken during the National Forest Inventory of Mexico in November, 2000, covering an area of approximately 4.5 km^2 each and (3) nine black and white digital orthophotos (from 1998 and 2000) obtained from INEGI (Aguascalientes, Mexico), which together cover the entire ejido. Field interpretation of the land cover associated to each GPS point as well as that of the colour aerial photos were performed with local assistants from X-Maben very knowledgeable of the land-use history of the sites. Detailed information on the history of 26 milpas used as sites for vegetation sampling in 2003 in a related study was also employed (see Dalle, 2006).

Once associated to a given land cover, the separability of the training sites for each image was tested using the Jeffries-Matusita, and the Transformed Divergence indices. For each image, training sites with very low separability (<1.0) were combined, while those with moderate separability were revised in order to improve their separability. In general, we aimed for a separability >1.9; however, in some cases separabilities could only be improved to 1.7. The final set of training sites defined for each image was then used in a maximum likelihood supervised classification.

The following land cover classes were identified for the 1976, 1988 and 1997 images: open water, wetlands, agricultural fields and open areas, young fallows (2–9 years), secondary forests (10–25 years), burned forests (less than approximately 5 years of having been burned) and mature forests >25 years. For the 1976 and 1997 images, two types of mature forests were identified: (1) more deciduous forests, including **k'an lu'um k'áax** and (2) more evergreen forests, generally corresponding to **yáax k'áax** in the local classification. It was not possible to distinguish these two forests types for the 1988 image since it was taken at the end of the rainy season when the deciduous trees had not yet shed their leaves. For 2000, the same land cover categories were identified as for 1997 and 1976, with the exception that young fallows ranged from 2 to 5 year in age, and the older fallows from 6 to 25 years. The 1991 image, for which only milpa/open areas land covers were extracted, was subjected to an unsupervised classification (ISODATA). The spectral classes from the ISODATA corresponding to milpas were identified, and this land class was extracted. Finally, a two-stage ''majority analysis'' was conducted to first remove unclassified pixels as well as isolated pixels of any land cover class in all images.

3.3.2. Accuracy assessment

During 2 weeks in April, 2004, a ground verification of the most recent image (2000) was conducted. We employed a stratified sampling design based on accessibility to randomly select a total of 27 sites to be verified. In each of the sites, four points were sampled in the form of a 270 m × 270 m. In each sampling point we drew a sketch map of the land covers observed in a 180 m × 180 m area centred around a single pixel (30 m × 30 m). This design provided land cover information for a total of 108 pixels.

For each land cover, we estimated its condition in 2000. For example, for a site that was a 2-year-old fallow in 2004 we would have estimated the age of the vegetation felled in 2002, and subtracted 2 years to estimate the age in 2000. The vegetation felled was estimated by the size of stumps and of trees spared in the field, and of the surrounding vegetation. Additional notes were taken on the type of substrate and variation in the vegetation cover (e.g. large gaps or patches of less dense or shorter vegetation) for each sampled pixel.

Results were analysed using a fuzzy analysis (Gopal and Woodcock, 1994) in order to account for ambiguities in class assignments. This occurred mostly at the threshold between land cover classes due to uncertainties in estimating the age of sites in the field, which we considered to increase with the age of the site. We therefore calculated a probable age range for each land cover, allowing ±1 year for sites estimated at ≤3 year in age, ±2 year for sites 3–15 years in age and ±4 years for sites ≥18 years in age. Sites estimated in the field to have been a milpa in 2000 were considered correctly classified if the map classification corresponded to ''milpa'' or to the age that was estimated to have been felled. In addition, in the case of pixels noted to have more than one land cover class, alternative ''correct'' answers were also accepted for secondary land cover classes covering >30% of the pixel. Finally, where species composition was considered to be intermediate between **k'an lu'um k'aax** (deciduous forests) and **yáax k'áax** (evergreen forests), either of these map classifications were accepted as correct. This fuzzy analysis was compared with a conventional ''crisp'' analysis (Stehman and Czaplewski, 1998), in which the reference category was taken to be the majority land cover estimated for the pixel in the field. For both analyses, formulae for calculating overall accuracies and associated confidence intervals for stratified samples were employed (Stehman, 1995). To calculate confidence intervals for user's and producer's accuracies, a bootstrap method (Efron, 1981) was used, following the script for MATLAB provided by Caswell (2001, p. 318).

The overall accuracy using the fuzzy criteria was 0.81 (S.E. = 0.04), while user's accuracies ranged from 0.71 for milpas to 0.91 for evergreen (**yáax k'áax**) forests (Table 3). The results for burned forests and for wetlands are inconclusive due to the small sample size ($n = 2$). Compared to the crisp analysis, the fuzzy analysis improved user's accuracies substantially for the classes milpa, young fallow, old fallow, and for the more deciduous **k'an lu'um k'aax** forest (Table 3). This indicates that a large proportion of the errors are due to ambiguities at the threshold between classes. Closer examination of the pixels remaining misclassified in the fuzzy analysis (mostly young fallows and secondary forest) suggested that approximately half of these might be due to errors at the boundary between different land classes, while the other half appear to be broader ''threshold errors'' than accepted in our fuzzy analysis. In combining young fallows with secondary forest, and the two mature forest classes, an overall accuracy of 0.91 (S.E. = 0.05) was achieved. In the analyses on land cover change described below we combined classes as much as possible in order to minimize the errors described.

Table 3
Producer's accuracy (PA) and user's accuracy (UA) for crisp and fuzzy analysis of accuracy assessment

Map class	n	''Crisp'' analysis		Fuzzy analysis
		PA	UA	UA[a]
Milpa	8	0.222	0.142	0.714 (0.27–1)
Young fallow	23	0.556	0.689	0.83 (0.65–0.96)
Secondary forest	26	0.559	0.483	0.79 (0.61–0.93)
Evergreen forest	29	0.804	0.910	0.91 (0.81–0.98)
Deciduous forest	18	0.783	0.759	0.79 (0.50–0.98)
Wetlands	2	1.000	0.500	0.50
Burns	2	n/a	0	0

[a] Confidence intervals are indicated in parantheses.

3.4. Spatial analysis

Analysis of land cover images were carried out in IDRISI version 132.22 (Clark Labs, Worcester, MA) and Arcview 3.3 (ESRI Inc., Redlands, CA, USA).

To examine patterns of agricultural expansion, forest maintenance and forest recuperation, transitions were calculated between agricultural cover and forest cover.

In this analysis ''agricultural'' combines milpa/open areas, young fallow and secondary forest, whereas ''forest'' includes mature forest and forest burns. Areas under cloud cover, water and inundated areas, as well as urban and built areas were excluded from this analysis.

A Chi-square test was used to compare the amount of the more evergreen **yáax k'áax** forests versus the more deciduous **k'an lu'um k'áax** forests which were converted to ''agricultural use'' in the 1976–1988 period versus the 1988–1997 period. The land cover class for 1976 was used to determine if forests later converted pertained to **k'an lu'um k'aax** or **yáax k'áax** forests. The statistic was calculated based on a 500 m × 500 m stratified random sample of pixels.

To examine changes in the distribution of milpas, the milpa/open area category from 1976, 1991 and 2000 was vectorized in IDRISI and exported to Arcview. In Arcview, each milpa/open

Table 4
Summary of restrictions on lands available for *milpa* agriculture, according to interviews with ejido presidents and local farmers

Period	Action	Level
(1) Restrictions on forest types permitted for milpa		
ca. 1955–1960	Prohibited to fell **ya'ax k'áax** with high densities (e.g. 15 ha^{-1}) of *Manilkara zapota* (chicle) and *Brosimum alicastrum* trees	Ejido
1979–1982	Milpas in areas with high densities of Mahogany denounced in ejido assembly	Ejido
1988–1991	Farmers encouraged by the OEPFZM to fell younger secondary forest for milpa and to use fertilizer	OEPFZM
1994	PROCAMPO program. No support provided for milpas felled from old growth **yáax k'áax** forests	Federal Government
1992–2004	Ejido presidents mention a wide variety of commercial timber species as protected	Ejido
(2) Reserves/delimited areas excluding milpa		
No date determined	Village reserves (**jal pach kaaj**). Areas of forest around several villages are prohibited to fell for milpa	Customary/Ejido
1980s	COPLAMAR reserve. Area of secondary forest enriched with timber and other economic species. Approximately 100 ha	Ejido–COPLAMAR Program
ca. 1986	Permanent forest area (community forestry). Area of 40,000 ha designated for timber management. Milpa prohibited, chicle and other extractive activities allowed	Ejido–OEPFZM Program
2001	"Laguna Azul" Ecotourism Reserve. Area of 35 ha. Milpa, as well as hunting and timber extraction prohibited	Ejido–Ecotourism Project

area layer was edited to remove all polygons corresponding to villages, other built areas, or pastures. In addition, all polygons less than 1 ha in coverage were eliminated, in order to avoid confusion with gaps or other disturbances. These coverages were then imported back into IDRISI.

Finally, we examined forest conservation in relation to accessibility. To do so, an accessibility index representing the ease of access from Señor was developed by creating an accessibility surface with the cost distance analysis module (COST) in IDRISI. We assumed travel by bicycle along roads of approximately 12 km/h, and travel by foot at a rate of 4 km/h along paths from these major roads. Separate access maps were created for two time periods (1976 and 1988/1997), taking into account the different road networks during these two periods. The maps were divided into access zones, such that zone 1 corresponds to approximately <30 min of travel, zone 2 from 30–60 min of travel and zone 3 from approximately 60–90 min of travel.

4. Results

4.1. Locally recognized forest conservation regulations

Interviews with the ejido presidents and field observations indicated the existence of several kinds of forest conservation regulations in X-Maben which restrict lands available for agriculture (Table 4). These are: (1) restrictions on felling certain forest types for agriculture, with emphasis on the tree composition and (2) specific forest patches or reserves which are protected from agricultural conversion, independent of their species composition. These include both ejido initiatives and programs promoted by non-governmental organizations (NGOs) and the federal government.

4.1.1. Restrictions on forest types

Restrictions on the type of forest allowed to be felled are meant to protect forests with high densities of economically important species. According to the ejido presidents, an agreement to protect dense stands of *Manilkara zapota* for chicle collection was made by the ejido assembly in the early years of the ejido (ca. 1955). *Brosimum alicastrum*, a canopy tree whose leaves are used for forage for horse and cattle, was also reported to be protected, although presidents only recalled denouncements for felling chicle. The first sales of commercial timber in X-Maben were reported to have occurred during the 1970–1973 period and ejido presidents from the early 1980s onwards specifically recalled denouncements for felling sites with the two most valuable species—mahogany (*Swietenia macrophylla*) and Spanish cedar (*Cedrela odorata* L.). Areas with high densities of other tropical hardwoods sold by the ejido (mainly as railroad ties) were reported to have become of increased concern to the ejidatarios in the 1990s, with one conflict over such an area having been reported in the 1997–2000 period.

A further restriction on forests felled for agriculture was reported by the local people to have been introduced in 1994 when the PROCAMPO (Programa de Apoyo Directo) was initiated. This is a federal program providing annual payments to poor farmers on a per hectare basis for land cultivated under a number of staple crops, including corn (Klepeis and Vance, 2003). Most families in X-Maben receive PROCAMPO support for their milpas. However, both ejido presidents and other people in the ejido explained that the payments are only for milpas felled from fallows and secondary forests. Felling of old growth forests, and in particular of the more evergreen **yáax k'áax** type, is not allowed whereas old growth forests of the more deciduous **k'an lu'um k'áax** type can be felled. Thus, since 1994 all old growth **yáax k'áax** forests in X-Maben are protected, with those violating this running the risk of losing their PROCAMPO payment (worth 1030 pesos per hectare in 2003).

4.1.2. Community reserves/protected areas

Three different types of community reserves exist in X-Maben: (1) customary village reserves, (2) a ''permanent forest area'', declared as part of the PPF and (3) reserves resulting from other government interventions.

The village reserves are patches of forest which surround each village. They are referred to in Maya as **jal pach kaaj** (literally ''the edge behind the village''), and are important sources of many forest products used for domestic purposes, such as firewood, poles and beams for construction, thatch, et cetera.

The permanent forest area or PFA is a reserve intended for commercial forest management which was established in ejido*s* throughout Quintana Roo as part of the Plan Piloto Forestal. Ejido assemblies were encouraged to prohibit agricultural activities in these areas which would form the basis of a management plan for mahogany with a 25-year rotation cycle. In X-Maben the PFA is estimated by the OEPFZM to consist of 40,000 ha. However, as discussed by Merino Pérez (2004, p. 158) for other ejido*s* in the area, the PFA has not been delimited on the ground, and has only become a physical reality as rotation blocks have been successively harvested. A sketch map prepared by the OEPFZM of the area showing the 25-year rotation plan for timber harvesting, is shown in Fig. 2b.

Two reserves in X-Maben exist as a result of additional government programs. The first is referred to as the ''COPLAMAR'' reserve. This was an area of secondary forest and fallows in which enrichment plantings of commercial timber species was carried out in the 1980s within the context of a government-funded program called COPLAMAR (Sullivan, 1987; Hostettler, 1996). Subsequently the ejido assembly agreed to prohibit felling of the COPLAMAR area, a protection which allowed it to regenerate to mature forests (see Section 4.2). It is now used in much the same way as the **jal pach kaaj**. Field observations and informal discussions indicated that more recent enrichment plantings of commercial timber species in young fallows carried out in the context of the Plan Piloto Forestal are conferred similar protection and could eventually lead to the regeneration of additional mature forest patches in agricultural areas.

The second and most recent reserve is an area of approximately 100 ha located at the edge of a large lake in the ejido. This was established in 2001 in the context of a government-supported ecotourism project and is the only reserve in which most forms of extraction and hunting are prohibited.

4.2. Landscape changes (1976–1997)

Overall statistics on land cover reveal a landscape dominated by mature forest cover, having decreased slightly from 80% in 1976 to 76% in 1997 (Fig. 3). Other land cover categories which decreased include forest burns, and milpa/open areas. Young fallow and secondary forest increased more than two-fold during the 21-year period.

Change statistics (Table 5) indicate that 79% of the area under forest cover in 1976 (55,349 ha) remained as forest in 1988 and in 1997. The annual rate of agricultural expansion

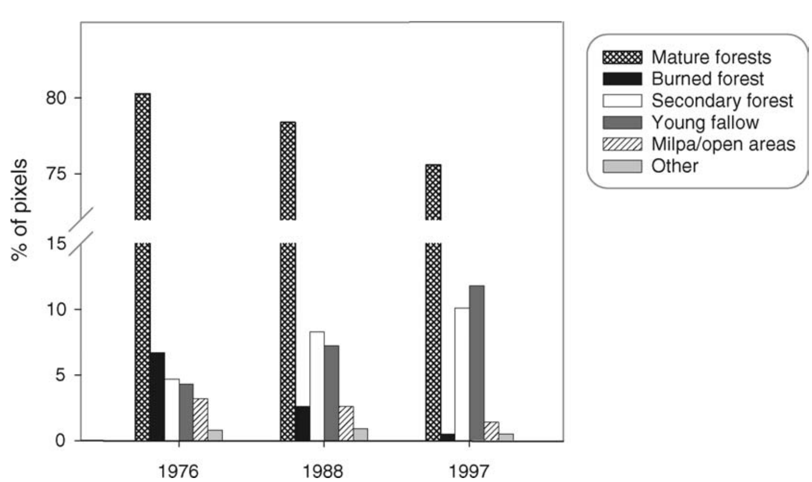

Fig. 3. Change in proportion of ejido lands under different land covers from 1976 to 1997.

Table 5
Land cover change statistics for the periods 1976–1988 and 1988–1997

Land cover change	1976–1988	1988–1997
Agricultural expansion		
Annual rate of conversion (ha/year)	702	858
Annual % of change relative to forest cover at t_1 [a]	1.0	1.3
Forest recuperation		
Annual rate of conversion (ha/year)	312	407
Annual % of change relative to agricultural cover at t_1	3.3	2.9
Net mature forest loss		
Annual % of change relative to forest cover at t_1	0.6	0.7
Agricultural permanence		
Hectares	5737	10,504
% of agricultural cover t_1	60.5	74.2
Forest permanence		
Hectares	61,616	57,629
% of forest cover t_1	88.0	88.2
Forest permanence 1976–1988–1997		
Hectares	55,349	
% of forest cover t_1	79.0	

[a] t_1 refers to the first year in each time period; for example, for the period 1976–1988, t_1 is 1976.

(transition from ‘‘forest’’ to ‘‘agricultural’’) increased slightly from the 1976–1988 period to the 1988–1997 period (702–858 ha/year), as did the annual rate of forest recuperation (312–407 ha/year). Expressed as a percentage of the original forest cover, this corresponds to a net annual transition of ‘‘forest’’ to ‘‘agriculture’’ of 0.6% in the first time period, and of 0.7% in the second.

Fig. 4 shows the spatial distribution of land cover transitions across the 21-year period. Visual examination reveals most zones of permanence of the agricultural zone concentrated around the biggest village, Señor. Important areas of agricultural expansion occurred along the road to San Antonio, and around San Antonio. Large areas under permanent forest cover in the south and east of the ejido correspond to the chicle harvesting areas and the PFA (Fig. 2). Some areas of milpa activity are evident within the PFA, these pertaining to some small settlements such as X-Nukankab and Tzukum, or ranches located alongside the highways (Fig. 2a). Forest recuperation tended to occur in areas far from the larger villages, and in some cases may be due to non-agricultural disturbances, such as hurricane damage. However, in other instances, such as in the northeastern corner and central part of the ejido, forest recuperation is due to cessation of milpa activity around abandoned ranches or old villages. With the exception of these abandoned ranches, the distribution of milpas before (1976) and after (1991 and 2000) the initiation of the PPF was found to be very similar (Fig. 5).

A significant difference ($X^2 = 16.2$, d.f. = 1, $p < 0.001$) was found between the 1976–1988 period and the 1988–1997 in the amount of **yáax k’áax** (more evergreen forests) and **k’an lu’um k’áax** (more deciduous forests) which were converted to agricultural land covers (milpas and fallows <25 years). In the first time period, 57% of agricultural expansion was due to conversion of the more evergreen **yáax k’áax** to agricultural land covers, whereas only 38% of this forest type was converted in the 1988–1997 period.

Finally, Fig. 6 shows that certain forest patches have been conserved despite being accessible. In the first accessibility zone (accessible within 30 min of travel), conserved forest patches include the village reserves around Señor and Chan Chen Comandante, as well as the area corresponding to the COPLAMAR reforestation project. In this latter case, the area consists of mature forest in 2000 that regenerated from secondary forest. In the second accessibility zone (30–60 min of travel), patches of conserved forest include two areas of the more valued **yáax k’áax** forest used for chicle harvesting and logging. In one case, the area is within the area designated by OEPFZM as PFA, in the other it is not.

5. Discussion

Previous remote-sensing assessments of community-based conservation initiatives have tended to seek correlations between maintenance or improvement in forest cover with the presence of specific conservation programs or tenure arrangements. Here, we have examined local land-use regulations to inform our analysis of land-use/land cover change on common property lands with a history of a community forestry program, the Plan Piloto Forestal. This approach reveals that local conservation practices are the result of a combination of both local initiatives and interventions of external agencies—including but not limited to the PPF. Furthermore, our study demonstrates that an understanding of local perceptions is important for analysing local land-use regulations. These points and their significance for community-based conservation are discussed in the sections that follow.

5.1. *Plan Piloto Forestal: interactions of community forestry with local institutions*

The case study of X-Maben reveals high rates of forest retention. The net annual rate of forest loss of 0.6–0.7% is lower than that for other inhabited landscapes in Mexico (ranging from 1 to 4%), and is only slightly higher than annual rates of forest loss (0.3–0.4%) reported for regions having protected areas at their core (Bray et al., 2004).

In their regional study of land-use/land cover change in Central Quintana Roo, Bray et al. (2004) found that forest cover was correlated with older, larger ejidos with greater volumes of commercial timbers. Our study provides insights into some of the conservation practices operating in one of these large forest ejidos. In particular, our results suggest a number of local conservation initiatives in X-Maben independent of the Plan Piloto Forestal. These include the existence of ejido regulations sanctioning the felling of dense chicle stands prior to the initiation of the PPF, the conservation of accessible chicle stands outside of the permanent forest area (PFA), protection of

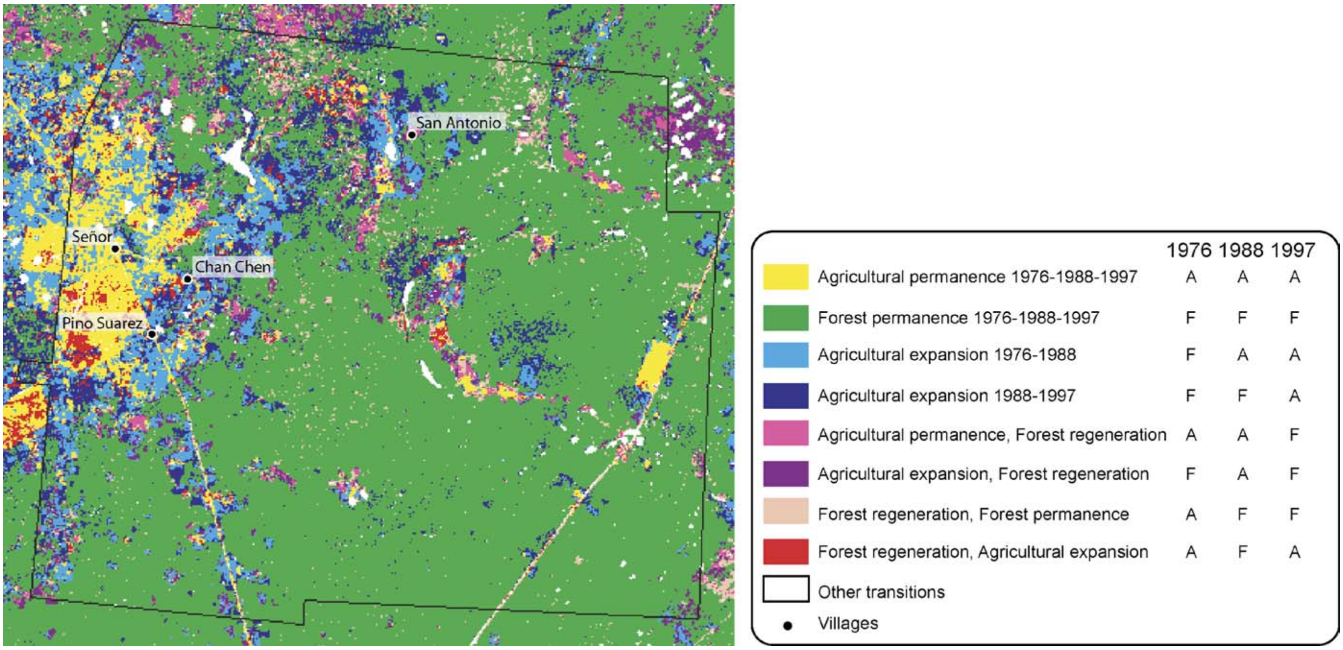

Fig. 4. Map of land cover transitions 1976–1988–1997. Codes for land covers: A = agricultural, F = mature forest.

customary reserves such as the **jal pach kaaj**, and more recently, the restriction on felling the more evergreen **yáax k'áax** forests associated with the PROCAMPO program.

Evidence of conservation regulations and practices predating the PPF is important in understanding some of the precedents which may have facilitated the implementation of this program. This is especially important to consider given interest in adopting the PPF model in other countries in Latin America (Bray et al., 2003; Merino Pérez, personnel communication). Our findings suggest a pre-existing conservation ethic that conferred protection to commercial forest products such as chicle, mahogany and cedar. Moreover, the

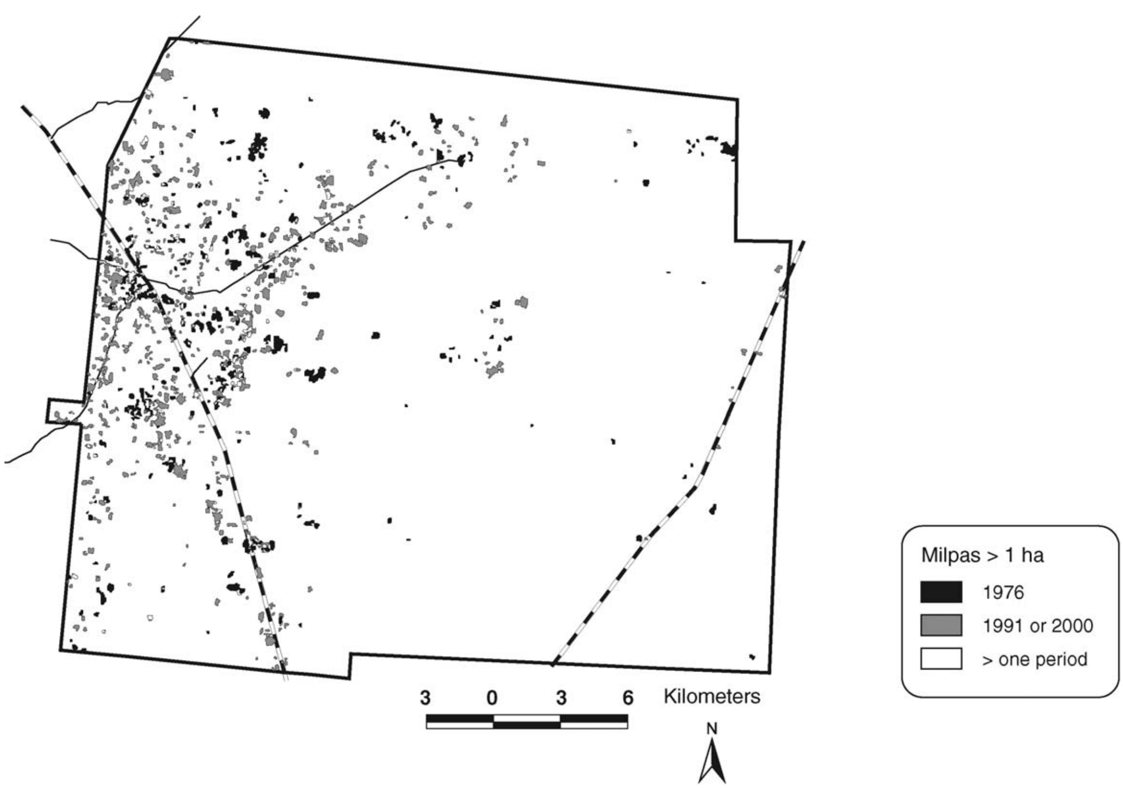

Fig. 5. Distribution of milpas before (1976) and after (1991, 2000) the initiation of the Plan Piloto Forestal in 1986. Only milpa covers over 1 ha in area are included; areas known to correspond to other open areas (villages, pastures and horticultural plots) were excluded.

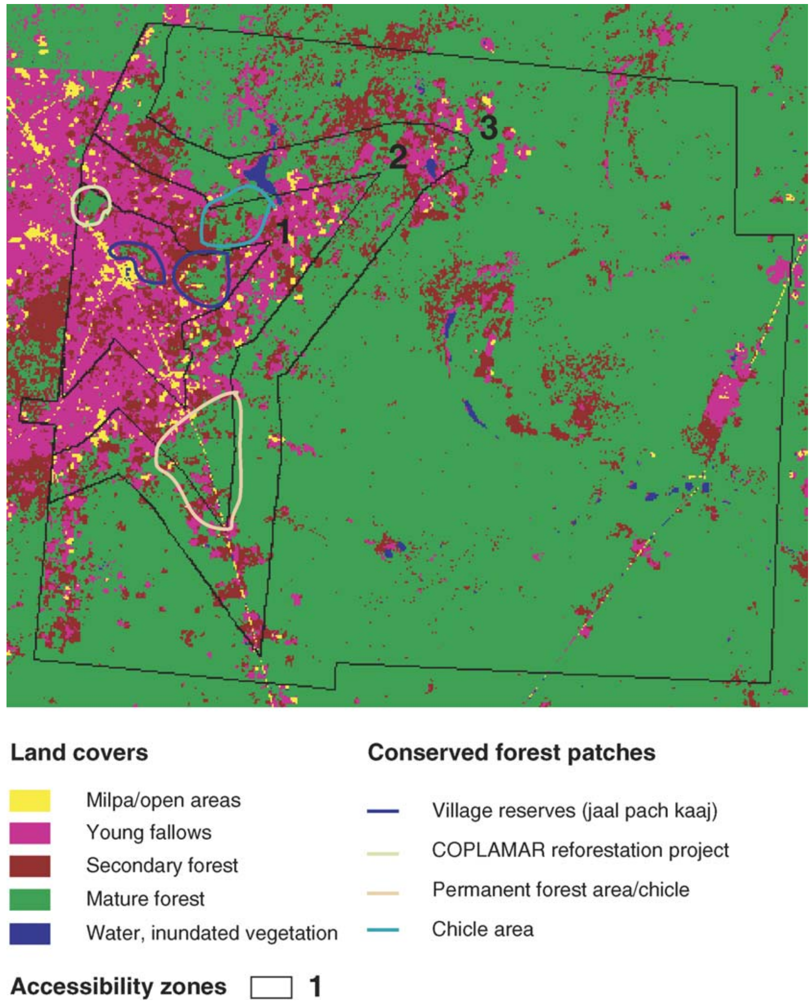

Fig. 6. Conserved forest patches in relation to accessibility zones (zone 1: <30 min, zone 2: 30–60 min, zone 3: 60–90 min of travel). Land covers are from 1997.

correspondence between chicle harvesting areas and the permanent forest area (PFA) suggests that the establishment of the PFA built on a pre-existing land-use pattern, in which large areas were reserved for chicle extraction. This hypothesis is further supported by the relatively constant distribution of milpa activity before and after the initiation of the PPF. This contrasts with Bray et al. (2004)'s assertion that the establishment of the permanent forest areas (PFAs) was a turning point in land-use practices, which ''effectively created a fixed 'internal agricultural frontier' in each ejido, forcing slash and burn agriculture to operate within more confined areas''. Our findings suggest that at least for X-Maben, the PPF benefited from land-use practices and corresponding institutions which developed as part of the chicle extractive activity. The main influence of the PPF has probably been to provide economic benefits from a wider range of forest products (especially precious timbers and tropical hardwoods), thereby increasing incentives for the maintenance of forest cover in a large part of the ejido which previously was mostly protected for chicle extraction.

While the chicle areas/PFA correspond to the largest extensions of conserved forests in X-Maben, it is important to note that the only mature forest maintained in the most accessible areas around Señor are the **jal pach kaaj** and the COPLAMAR reserve. To date the PPF model (which concentrates forest management activities in the PFA) has not contributed to maintaining forest cover in the agricultural areas. However, such forest patches can be important for promoting dispersal and rapid regeneration of shifting cultivation fields and are important sources of firewood and other forest products (see Dalle, 2006).

The COPLAMAR experience shows that enrichment plantings of commercial timber species may be a way to promote the regeneration of older forest patches within the agricultural matrix. Indeed, although this project was active only in the 1980s, the area of secondary forests in which enrichment plantings were made of commercial species was subsequently protected by an ejido agreement, leading to the regeneration of a 100 ha patch of mature forest in the 1988–1997 period. In recent years plantings of species such as mahogany and cedar in agricultural fallows has been promoted by the OEPFZM; if the COPLAMAR experience is any indication, these activities may lead to the protection of additional forest patches within the agricultural areas.

5.2. The importance of local forest classification for understanding local conservation practices

Our findings indicate that a recognition of the local forest classification and associated values is important for understanding the land-use/land cover dynamic, and how external programs are interpreted at the local level. This is the case of the PROCAMPO program which – at least according to the local perception – provides support only for milpas not felled from old growth **yáax k'áax** or evergreen forests, thus conferring protection to such forests. Interestingly, official documents of the PROCAMPO program do not indicate any restriction on felling old growth forests (e.g. SAGARPA, 1995). Rather, PROCAMPO payments, which are made on a per hectare basis, are supposed to be restricted to land under permanent cultivation only. This condition is intended to alleviate pressure on forested lands, as farmers are expected to use the support to intensify production (Klepeis and Vance, 2003).

Although we do not have any specific information on how PROCAMPO officials implemented the program locally, it appears that in X-Maben, where nearly all agricultural production is based on shifting cultivation, the goal of alleviating pressure on forests was met by encouraging farmers to avoid felling mature forests. However, the fact that local farmers reported that this applies only to **yáax k'áax** and not to **k'an lu'um k'áax** forests is most certainly a local interpretation. Our interviews and informal discussions indicate that the term used in Spanish to refer to mature forests, ''monte alto'', is considered by the local Maya population to be synonymous to the **yáax k'áax** forest type only. Thus, while PROCAMPO officials may have encouraged farmers to avoid felling ''monte alto'', the local population would have interpreted this to refer to **yáax k'áax** only.

The protection of **yáax k'áax** forests conferred by the PROCAMPO represents an extension of earlier community norms and regulations which protected commercial forest products such as chicle, mahogany and Spanish cedar that local people reported to be associated to the more evergreen **yáax k'áax** forest type (Table 1). The significant decrease in the proportion of **yáax k'áax** forests felled in the 1988–1997 period compared to the 1976–1988 period provides evidence that this progressive protection of the more evergreen **yáax k'áax** forest type has led to an observable effect on land-use trends. The analysis of local land-use regulations and of the Maya perception of local forest types therefore clearly provides important insights into the land-use dynamic that would not have been obvious if only the conservation actions related to the Plan Piloto Forestal program had been considered.

One important consequence of the local perception of forest types is that agricultural expansion continues on the more deciduous **k'an lu'um k'áax** forests. Indeed, within the permanent forest area (PFA) milpa is generally felled either from **k'an lu'um k'áax** forests or from the intensively used **laaj kaj** vegetation associated with ancient Mayan ruins (Table 1). On the long-term old growth **k'an lu'um k'áax** forests may not be adequately protected in X-Maben and potentially other ejidos in the region. Although recent floristic work in the Yucatan peninsula has aimed to better describe variations in forest communities (e.g. Rico-Gray et al., 1988; White and Darwin, 1995; Sanchez-Sanchez and Islebe, 2002; White and Hood, 2004), to our knowledge no floristic studies have described these locally recognized forest types. Future research may therefore want to address the significance of the less-valued deciduous **k'an lu'um k'áax** for global biodiversity conservation, and the extent to which this forest type is represented within the PFAs or other protected forest patches.

6. Conclusions

This study has shown that the joint analysis of local land-use regulations and of spatial trends in land-use/land cover change is an effective means to identify some of the social factors that drive conservation actions on common property lands. In the case study presented here, land-use regulations were not limited to the PPF community forestry program. The analysis of land-use regulations unrelated to the PPF revealed that customary village reserves and protection of enrichment plantings of commercial forest products have led to the maintenance of forest patches in the more accessible agricultural areas, while agricultural expansion is focused on less-valued forest types poor in commercial forest products. The findings provide important insights for forest conservation by pointing to the need for further study of the conservation-significance and distribution of the less-valued forest types, while suggesting that the enrichment plantings of valued species may be an effective means to promote the regeneration of further forest patches in the agricultural areas.

Our research also demonstrates how an understanding of cultural perceptions and in particular the folk classification and indigenous terminology used to distinguish forest types is important for the proper interpretation of local land-use regulations and of trends in forest conservation. Both researchers and practitioners should heed increased attention to folk classification systems and familiarize themselves with indigenous terminology in order to improve analyses of land-use dynamics as well as to achieve better collaborations and conservation outcomes on common property lands.

Finally, the historical approach used here (examining both land-use regulations and land-use/land cover data before and after the initiation of community forestry) revealed a pre-existing land-use pattern that may have facilitated the implementation of the Plan Piloto Forestal. Careful analysis and consideration of the historical antecedents and community institutions that have contributed to the success of the PPF in Quintana Roo will be important for the successful application of the PPF model to other socio-economic and cultural contexts where such precedents may not exist.

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