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Deforestation Processes in the State of Quintana Roo, Mexico: The Role of Land Use and Community Forestry

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Abstract

In this study, we evaluate deforestation processes and its relationship with different production and conservation land uses in the state of Quintana Roo in the Yucatan Peninsula, Mexico. We also analyzed deforestation in ejidos (common property) with and without community forest management (CFM) that were categorized according to their degree of development and participation in CFM. The results show that the principal land uses for most deforested areas were for livestock and maize production. Mechanized agriculture and urban development related to tourism also represented important deforestation threats with high rates of annual forest conversion from 2001 to 2013. However, fire was also found to be a major threat to forest cover loss in Quintana Roo, with the highest rate. Low deforestation was associated with milpa agriculture, conservation or protected areas, and CFM. Ejidos with more development and participation in CFM tend to have a significantly lower proportion and lower overall rates of deforestation compared with ejidos without CFM. Regional conservation strategies that promote and integrate both land sparing and land sharing approaches are recommended and discussed.

Keywords

deforestation, community forest management, protected areas, geographical information systems, Quintana Roo, REDD+

Introduction

Halting deforestation in the tropics has been a considerable challenge since the immediate and underlying causes of the problem are often diverse, complex, and interrelated, and occur at different scales under the influence of local, national, and international factors (Geist & Lambin, 2002). Although the annual rate of deforestation has decreased in Mexico in the last two decades, more than 100,000 ha of forests continue to be cleared annually (FAO, 2015), the majority of which occurs in tropical forests, such as in the Yucatan Peninsula (Céspedes-Flores & Moreno-Sánchez, 2010; Challenger & Soberon, 2008; Velázquez et al., 2002). Determining the direct and underlying causes of deforestation within the landscape is crucial to the development of effective forest conservation strategies (Kissinger, Herold, & De Sy, 2012; Salvinir, Herold, Sy Kessinger, Brockhaus, & Skutsh, 2014).

At a global scale, loss of tropical forest cover is mostly due to the expansion of agricultural and livestock land uses, with economic profitability and population growth being the major underlying forest conversion drivers; other factors, such as protected areas (PA) and poverty, are associated with lower deforestation; while, at this scale, forest management and communal land tenure do not seem to show clear relationships with higher or lower deforestation in the tropics (Ferretti-Gallon & Busch, 2014). As a consequence, there are divergent opinions in terms of the optimum land use strategies for conserving tropical forests and the biodiversity they host: (a) on one

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extreme, there are proponents of exclusive strategies, such as PA, since the rural communities of the tropics can be considered to be part of the deforestation problem (Brandon, 1995; Bruner, Guillison, Rice, & da Fonseca, 2001); (b) on the other, there are those who promote tropical forest conservation by local communities that have formally recognized rights for the use, management, and benefit of their forest resources (Hayes, 2006; Lele, Wilshusen, Brockington, Seidler, & Bawa, 2010; Nagendra, Pareeth, & Ghate, 2006). This land use strategy defines the term *Community Forest Management* (CFM) or community forestry precisely (Charnley & Poe, 2006). While proponents of PA question the effectiveness of CFM for conservation of the tropical forest and its biodiversity, those who favor CFM question the exclusivity of the participation and benefit for the local communities, as well as the effectiveness of the PAs (and their related institutions) in terms of actually halting deforestation.

Also related to planning optimal land-use strategies that promote biodiversity conservation in tropical forest landscapes is the land sparing versus land sharing debate. While trying to meet simultaneous goals of producing food (and other products) for human populations and conserving biodiversity, land sparing involves implementing intensive, high-yield systems for the production of foods and natural resources while leaving exclusive areas for biodiversity conservation such as PA; on the other hand, land sharing involves implementing more extensive lower yield systems that integrate and can be complementary to biodiversity conservation, as exemplified by agroforestry, slash-and-burn agriculture (or milpas) and CFM (Kremen, 2015). A prominent study, exemplifying Ghana and northern India, has proposed land sparing as a more effective strategy for biodiversity conservation (Phalan, Onial, Balmford, & Green, 2011), but it has also been strongly contested, claiming that the real world is not so black and white, and many countries lack experience in effective PA management, have a long history of traditional and less intensive agricultural practices and land uses, or contain regions were intensive agricultural land uses are not environmentally suitable (Fischer et al., 2014). Thus, evaluating the impacts on forest cover change of different land uses, both for production and conservation, is important for effective biodiversity conservation and sustainable development planning, especially at regional and local scales.

Some studies conducted in Mexico have demonstrated empirically that ejido land with CFM (land sharing) is associated with low rates of deforestation and the maintenance of forest cover (Barsimantov & Kendall, 2012; Deininger & Minten, 1999; DiGiano, Ellis, & Keys, 2013). Ellis and Porter-Bolland (2008) demonstrated this reduced deforestation in ejidos with CFM in the central part of the Yucatán Peninsula and more recently, Hodgdon, Hughell, Hugo Ramos, and McNab (2015) also shows greater conservation in tropical forests with CFM in the Petén region of Guatemala compared with other zones within the Maya Biosphere Reserve. However, a study at national scale and at municipality level suggests greater deforestation in ejido lands compared with other land tenure regimes such as private property (Bonilla-Moheno, Redo, Clark, & Grau, 2013), although the spatial resolution, scale of analysis, and results of that study were questioned by Skutsch, Mas, Bocco, Bee, Cuevas, and Gao (2014). With regard to PA, Brandon, da Fonseca, Rylands, and da Silva (2005) showed the potential of a PA system in Mexico to conserve an important part of its biodiversity without competing with human settlements or agricultural land uses. Likewise, Figueroa and Sanchez-Cordero (2008) indicate the effectiveness of most PA in Mexico in deterring deforestation and conserving important natural ecosystems. Some proponents of PA in Mexico have even claimed that deforestation is associated with common property land tenure regimes (e.g., ejidos) and that PA are the only way to conserve biodiversity (Centro de Derechos Jurídicos y Ambientales, 2015). The particular debate surrounding the role of CFM and PA land uses in the conservation of Mexican forest cover is very important, considering the country has worldwide prominence for its land area under communal land tenure or social property, which is estimated to represent approximately 60% of the national area of temperate and tropical forest (Madrid, Nuñez, Quiroz, & Rodriguez, 2009).

The purpose of this study was to determine the impacts of different land uses on deforestation processes occurring in the state of Quintana Roo in the Yucatan Peninsula, Mexico. We show how forest cover change varies within the state according to regional land uses, and identify the different direct and underlying causes of deforestation. We further explore the effectiveness of PA and CFM by ejidos in conserving forest cover in the state. Community forestry in the region involves selective logging for high-value timber, such as mahogany, and other common tropical species of lesser value (Ellis, Kainer, et al., 2015). In the Yucatan Peninsula, reducing deforestation and conserving biodiversity is a national priority, and has generated much discussion and opinion regarding the optimal land use strategies to pursue in order to realize this objective. The federal government, through programs of the National Forestry Commission (CONAFOR), promotes greater production and strengthening of the forestry sector, including greater investment in and improvement of community forestry enterprises, all the while integrating the objectives of eliminating deforestation and conserving biodiversity (Gobierno de la República, 2014). Linked with CONAFOR, the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) initiative also implements activities to reduce deforestation and to conserve tropical forest cover, promoting CFM, low-input traditional agriculture, and agroforestry as conservation strategies (CONAFOR, 2010). Furthermore, and in synergy with the other programs mentioned, the National Commission of Natural Protected Areas (Comisión Nacional de Áreas Naturales Protegidas, Secretaría de Medio Ambiente y Recursos Naturales [CONANP]), in addition to promoting the establishment of formal PA, voluntary community conservation areas, and priority conservation areas, also promote strengthening local natural resource-based economies that help conserve biodiversity (CONANP, 2015). The results presented in this article provide important insights as to how different land uses impact forest landscapes in the region and the potential of both land sparing (e.g., PA) and land sharing (e.g., CFM) land use strategies in halting deforestation and conserving forest cover in the region.

Methods

Forest cover change between 2001 and 2013 and its associated current land uses or proximate causes were evaluated and mapped in the Yucatán peninsula. This process integrated various methods, such as literature analysis, field validation, application of Geographic Information Systems, and an expert workshop (Ellis, Romero-Montero, & Hernandez, 2015). Analysis of deforestation was based on georeferenced data from Hansen et al. (2013), which are available on the Global Forest Change (GFC) website of the University of Maryland (http://earthenginepartners.appspot.com/science-2013-global-forest) and the Global Forest Watch (http://www.globalforestwatch.org) website. These data were produced with remote sensing techniques, using LANDSAT images with a resolution of 30 m per pixel. The data obtained from GFC and used in this analysis include the loss and gain of forest coverage from 2001 to 2013, derived from algorithms that detect the removal (or recovery) of vegetation biomass using a threshold of 50% to classify each pixel as ''deforested'' or ''recovered.'' The data produced by Hansen et al. (2013) represent an input of information about historical deforestation that is free, transparent, and easily available, as well as being of sufficient quality for use as an instrument for guiding and implementing REDD+ strategies (TNC, 2014).

The regionalization of different land uses and deforestation causes first took into account the georeferencing of the information derived from published articles, theses, and reports regarding the different causes or ''drivers'' of deforestation in the region. Subsequently, field validation was conducted, which entailed collecting ground-truthing points and recording current land use or proximate cause of sites that were deforested between 2001 and 2013. A total of 520 deforestation locations were sampled, which were distributed at random within 13 polygons of 80×80 km, also distributed at random throughout the Yucatán Peninsula (Ellis, Romero-Montero, et al., 2015). Likewise, additional information was obtained related to sites with forest fires recorded by CONAFOR (2013), hurricane trajectories (CONAGUA, 2012), the location of different types of crops and livestock production (SAGARPA, 2012), location of regions and ejidos with CFM (RAN, 2007; SEMARNAT, 2015), and the location of PA in the Yucatan Peninsula (CONANP, 2007). Based on the spatial integration of all the information obtained and using images available in Google™ Earth Pro (7.1.5.1557), regions representing predominant land uses for agricultural and forestry production or conservation purposes were zoned in the Yucatan Peninsula. Since forest fires were later noted as a very prominent and significant cause for the loss of forest cover, although not precisely considered a land use, these regions were also included and zoned in the map.

The land use (or forest cover change) regionalization map produced was subsequently evaluated and validated by experts from NGOs and state governmental agencies from Campeche, Quintana Roo, and Yucatán working in the fields of environment, forestry, and sustainable development in the Yucatán Peninsula and under the framework of the Observatorio de la Selva Maya. During the workshop ''Analysis of the direct and underlying factors behind deforestation in the Yucatán Peninsula,'' held on June 24, 2015 in Tatankin, Yucatán, the experts worked in groups for each state reviewing and making observations and corrections regarding the regions and limits of the regionalization of land uses, as well as providing and clarifying in more detail the direct causes of forest cover change and the underlying factors present in each land use region.

Using the final product of the land use/forest cover change regionalization map presented in Figure 1 (Ellis, Romero-Montero, et al., 2015) and applying the GFC data, the area, percentage, and rate of forest coverage loss was determined that corresponded to the following categories of land uses (or forest cover change) in the state of Quintana Roo: (a) mechanized agriculture, (b) slash and burn or milpa agriculture, (c) sugarcane cultivation, (d) conservation, (e) community forestry, (f) livestock production with maize, (g) fires, (h) maize monocrop cultivation, and (i) touristic development (Figure 1).

The region of conservation coincides with the six main PA of the state: Balaan Kaax, Manglares de Nichupte, Sian Kaan, Tulum, Uaymil, and Yum Balam. Similarly, deforestation processes were evaluated within the formal limits of these six PA to also evaluate forest cover change within the PA boundaries or core zones. The annual rate of forest cover loss was calculated by subtracting the percentage of forest cover loss from the percentage of forest

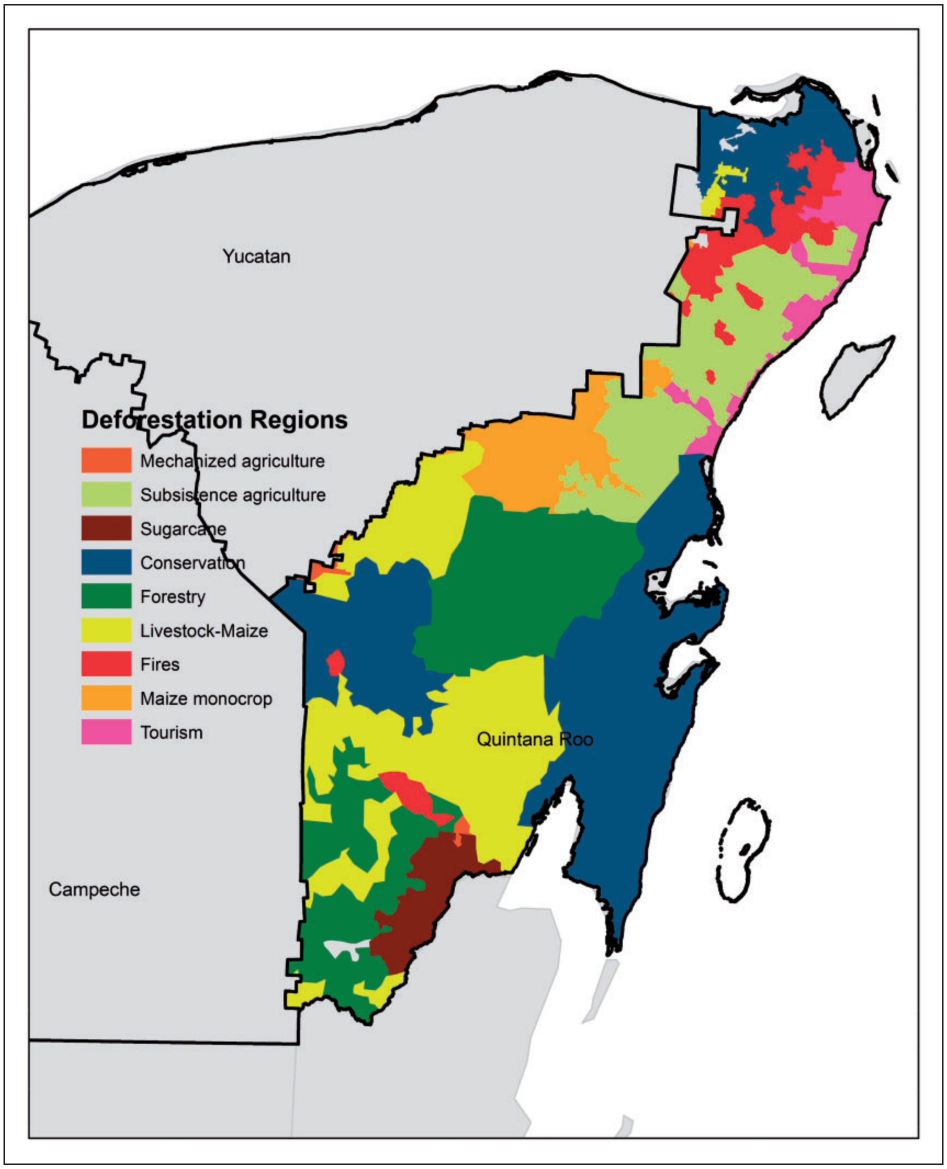

Figure 1. Map of regionalization of current land uses and direct causes of deforestation in the state of Quintana Roo (Source: Ellis, Romero-Montero, et al., 2015).

coverage gain and dividing by 13, which is the number of years evaluated (2001–2013). It is important to note that, while the GFC data of forest loss has a certainty greater than 80% in the Yucatan Peninsula (Ellis, Romero-Montero, et al., 2015), underestimations and uncertainty in the Hansen et al. (2013) data pertaining to gains or regeneration of forest cover mean that the rates calculated for this study only serve as quantitative indicators of the deforestation and are unsuitable for comparison with deforestation rates in other regional or national studies. Also for these reasons, we only consider and evaluate deforestation in this study and not forest recovery.

To further determine the relationship of CFM and forest cover change in the state, we use the GFC data to determine the area, percentage, and annual rate of deforestation in ejidos with different types or levels of CFM adoption, based on the 2015 CONAFOR ejido typology for the state of Quintana Roo. The CONAFOR typology and types of ejidos evaluated consist of the following: (a) Type 1 ejidos with sufficient forest resources and forestry potential, but which have not been involved with CFM (at least within the past 15 years); (b) Type 2 ejidos with CFM but that only sell standing trees to buyers and do not participate in forestry operations); (c) Type 3 ejidos with CFM that sell cut logs and participate in forestry operations; and (d) Type 4 ejidos with CFM that sell cut logs and sawnwood processed in their own sawmill and participate in all forestry operations.

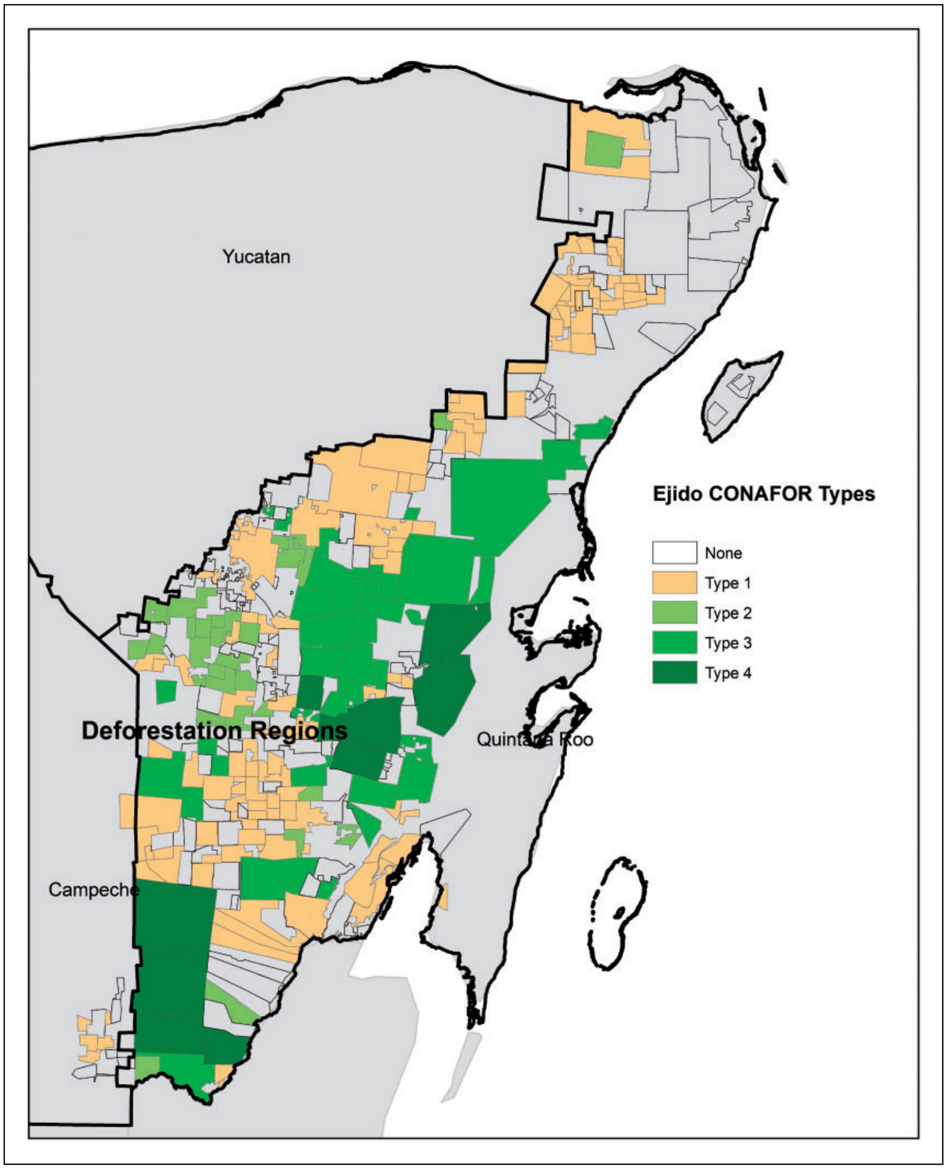

Figure 2. Map of Ejidos in Quintana Roo with different types of forestry management according to the CONAFOR typology: None, without CFM adoption and forestry potential; Type 1, without CFM adoption but with forestry potential; Type 2, with CFM but only sale standing timber and do not participate in forestry operations; Type 3, with CFM that sale cut timber and participate in forestry operation; and Type 4, with sale of cut timber and lumber cut with their own sawmill and participate forestry operations.

The georeferenced data from these ejidos were obtained from the Registro Agrario Nacional (RAN, 2015). The data of ejidos with CFM in the last 10 years in the state of Quintana Roo were obtained from the state office of SEMARNAT in Chetumal, Quintana Roo (SEMARNAT, 2015) and the forestry typology of ejidos was obtained from the CONAFOR state office in the same city. Figure 2 shows the CONAFOR ejido typology in the state of Quintana Roo. As can be noticed in Figure 2, Type 1 ejidos (without CFM but with forestry potential) are located throughout the state and within the same forest regions as Type 2–4 ejidos (with CFM), and by considering only Type 1 ejidos as those without CFM, we eliminate close to 100 ejidos which may be either too small, without suitable forest resources, or in unsuitable regions for CFM adoption, thus controlling these important factors when comparing the impact of CFM in ejidos of Quintana Roo. However, we recognize that adoption of CFM by ejidos can be a very complex matter where, governance, technical support, government requirements and regulations, and other factors can influence ejidos in practicing CFM. Of all the ejidos in the state (284), a total of 183 were analyzed to compare CFM adoption and degree of participation, based on the CONAFOR 2015 list of ejido typology. Of this sample, 72 ejidos had adopted CFM and 111 had forestry potential but had not adopted CFM.

Finally, the statistical differences in ejido size, deforested areas, percent deforested areas, and annual deforestation rate were evaluated between ejidos that have been practicing CFM (Types 2–4) and ejidos with forestry potential but without CFM adoption (Type 1) using the nonparametric Mann–Whitney test and also between each ejido Type (Type 1, 2, 3, and 4) using the nonparametric Kruskal–Wallis test and Steel–Dwass–Critchlow–Fligner procedure for multiple pairwise comparison of different ejido types.

Results

The analyses of the deforestation processes associated with different land use or direct causes in Quintana Roo are summarized in Table 1. Most of the deforested area between 2001 and 2013 was associated with livestock-maize production zones (112,157 ha) in the state, having a high annual deforestation rate of −0.70 during this period. The underlying causes identified for the deforestation related to livestock and commercial maize production were principally government agricultural subsidy programs (e.g., PROCAMPO and PROGAN), migration, and population growth. Fires alarmingly represented the second largest cause of forest cover loss (57,746 ha) in Quintana Roo and represented the highest annual rate of loss (−1.92). Quintana Roo is characterized by a high frequency of hurricanes, followed by forest fires that influence to a large extent the processes of forest cover loss and recovery in the region. The forest cover loss by impacts of fire can be seen mostly in the northern and central regions of the state, more recently related to hurricanes Wilma (2005) and Dean (2007), respectively. While mechanized agriculture (mainly for maize cultivation) is not a wide-spread land use in the state landscape, the rate of deforestation and expansion as a result of this land use is the second highest (−1.70). Mechanized agriculture is a common productive activity in the municipality José María Morelos, and more recently in the municipality Bacalar, and is practiced by Mennonite communities that have recently migrated. The underlying factors identified for this recent deforestation process in the state were commercial profitability, migration, and facilitation by government and credit institutions. Deforestation due to urban and infrastructural growth in regions of touristic importance represents the third highest annual rate (−0.77). This region is located mainly on the coast of the Riviera Maya and in Cancún. Population growth largely due to development and growth of the tourism sector are the principal underlying causes of forest cover loss in urban and tourist zones in northeastern coastal region of the state. To the south of the state, the regions of sugarcane cultivation and commercial maize production are found, which also present high rates of deforestation (−0.74 and −0.70, respectively). The determined underlying causes for the conversion of forest to sugarcane were economic profitability and credit programs offered by local sugar mills to local agricultural producers in the south.

Lower rates of deforestation were associated with forest management or CFM zones (−0.29; located in the center and south of the state), and conservation zones (that coincides with the six main PA described earlier; −0.18). The average deforestation rate within the core limits of the PAs, excluding adjacent or buffering areas and mainly without population, is of −0.10, demonstrating their effectiveness in terms of reducing, although not eliminating deforestation. The zones representing the lowest deforestation rate within the landscape of Quintana Roo were associated predominantly with milpas or subsistence agriculture land use (−0.06) located

Table 1. Deforestation Associated With Land Use Regions and Fire in Quintana Roo, Based on the Regionalization of Ellis, Romero-Montero, et al. (2015).

Current use/direct cause	Total area (ha)	Forest coverage loss (ha)	Forest coverage loss (%)	Forest coverage gain (%)	Deforestation rate
Fires	204,460	57,746	28.24	3.23	−1.92
Mechanized Agriculture	15,788	3,714	23.53	1.37	−1.70
Tourism	151,235	20,062	13.27	3.31	−0.77
Sugarcane	132,190	15,313	11.58	1.92	−0.74
Livestock-Maize	283,425	112,157	12.77	3.28	−0.70
Maize	245,900	31,465	12.80	5.71	−0.55
Forestry	817,394	50,046	6.12	2.41	−0.29
Conservation	1,284,990	35,885	2.79	0.51	−0.18
Milpa (Subsistence)	497,035	6,825	1.37	0.61	−0.06

mostly in the central and northern portion of the state. The underlying factors related to forest cover change processes in the milpa zones were related to poverty or subsistence needs as well population growth. It is also important to note that deforestation is lower in the milpa zones than in zones with conservation land use or PA, despite the fact that the region of milpas has a greater human presence and anthropogenic intervention than that of the PAs.

With the aim of more precisely and objectively determining the deforestation processes related to CFM in ejidos of Quintana Roo, the loss of forest cover between 2001 and 2013 was evaluated in ejidos with different CFM typologies described earlier. Table 2 summarizes the descriptive statistics of total area (ha), forest cover loss (ha), percentage and annual rate of forest cover loss in ejidos with CFM (Types 2–4), and without CFM but with potential for adoption (Type 1). Ejidos that practice CFM (Types 2–4) are significantly larger than Type 1 ejidos ($p < .0001$), all being over 2,500 ha and averaging 17,103 ha, more than double the size of Type 1 ejidos averaging 7,687 ha. Because Type 2 to 4 ejidos practicing CFM are larger in size, the average deforested area (1,123 ha) in these ejidos was larger ($p = .031$) compared with Type 1 ejidos (885 ha; Table 2). However, Type 1 ejidos had a significantly larger ($p < .0001$) proportion of the ejido deforested (mean = 11.5%) compared with Type 2 to 4 ejidos with CFM (mean = 8.1%). Deforestation rates were also significantly lower ($p = .036$) in Type 2 to 4 ejidos with CFM (mean = −0.43) compared with Type 1 ejidos that have not adopted CFM (mean = −0.59), demonstrating that the ejidos with no community forestry can present deforestation rates of 0.2% more on average, compared with those with CFM.

The results comparing the four types of ejidos representing different degrees of participation and involvement in CFM indicated that increased participation and vertical integration was associated with less deforestation. Table 3 compares descriptive statistics of total area (ha), forest cover loss (ha), percentage, and annual rate of forest cover loss for Type 1, 2, 3, and 4 ejidos. The Kruskal–Wallis test also showed significant differences in ejido size with respect to typology ($p < .0001$). Type 3 and 4 ejidos (mean = 18,225 ha and mean = 45,241 ha, respectively) were much larger than Type 1 and 2 ejidos (mean = 7687 ha and mean = 6657 ha, respectively). Pairwise comparisons of the four types of ejidos show that while Type 1 and Type 2 ejidos are not significantly different in size ($p = .46$), Types 3 and 4 are significantly larger in size ($p < .0001$) than Types 1 and 2. Also, Type 4 ejidos are significantly larger ($p = .004$) than Type 3 ejidos and Type 3 ejidos are significantly larger ($p = .005$) than Type 2 ejidos; showing that vertical integration in community forest enterprises are more prevalent among large ejidos with greater potential of forest resources and yields. In terms of forest loss, ejido types also showed significant differences (Kruskal–Wallis test, $p = .001$). Type 3 and Type 4 ejidos, which are larger, have greater forest loss (mean = 1,350 ha and mean = 1,908 ha, respectively) than Types 1 and 2 (mean = 884 ha and mean = 587 ha, respectively). However, pairwise comparison show that only Type 4 communities differed significantly from Types 1 and 2 ($p = .009$ and $p = .003$, respectively).

Moreover, the Kruskal–Wallis test shows that percent forest cover loss in the four types of ejidos are significantly different ($p < .0001$). With Type 4 ejidos clearly showing lower portions of forest cover loss (mean = 4.2%) than Type 2 and Type 3 ejidos (mean = 8.7% and mean = 8.6%, respectively), and Type 1 ejidos having the largest proportion of forest cover loss (mean = 11.5%) (Figure 3). Pairwise comparisons indicate that Type 4 ejidos have significantly less proportions of deforested areas than Types 1 and 2 ($p = .001$ and $p = .016$) and Type 3 ejidos also have significantly lower ($p = .037$) proportions of deforested areas than Type 1 ejidos. A similar pattern is observed with respect to annual deforestation rate in the four types of

Table 2. Descriptive Statistics of Total Area (ha), Loss of Forest Coverage (ha), Percentage and Annual Rate of Forest Coverage Loss, in Ejidos of Quintana Roo With CFM (Types 2–4; $n = 72$) and Without CFM But With Forestry Potential (Type 1; $n = 111$).

Statistic	Area of ejido (ha) without CFM	Area of ejido (ha) with CFM	Loss (ha) without CFM	Loss (ha) with CFM	% Loss without CFM	% Loss with CFM	Loss rate without CFM	Loss rate with CFM
Average	8,067	17,103	884	1,123	11.5	8.0	−0.59	−0.42
Minimum value	150	2,457	0	60	0	1.1	−2.43	−2.09
Maximum value	63,244	118,223	14,986	5,427	33.7	28.5	0.19	0.01
Std. Dev.	9,658	21,148	1,535	1,171	6.6	5.0	0.25	0.34
Lower limit of CI (95%)	5,851	12,099	663	835	10.2	6.8	−0.69	−0.50
Upper limit of CI (95%)	9,512	22,108	1,105	1,411	12.7	9.3	−0.50	−0.34

CFM = community forest management.

Table 3. Total Area (ha), Loss of Forest Coverage (ha), Percentage and Annual Rate of Forest Coverage Loss, in Ejidos of Quintana Roo With and Without Community Forestry Management (CFM).

Variable	CFM type	No. Obs	Minimum	Maximum	*M*	*SD*
Ejido size	1	111	150.20	63244.20	7686.80	9658.24
	2	28	2540.72	18037.80	6657.46	3631.00
	3	35	2457.25	118223.00	18225.15	22223.60
	4	9	13227.80	85030.60	45241.41	21916.92
Forest loss (ha)	1	111	0.00	6427.84	884.56	1171.12
	2	28	60.45	1866.26	587.86	437.61
	3	35	79.00	5327.05	1350.02	1391.04
	4	9	687.52	4894.87	1908.53	1415.02
% Loss	1	111	0.00	33.80	11.52	6.61
	2	28	1.12	17.79	8.68	3.84
	3	35	1.19	28.56	8.63	6.07
	4	9	2.48	6.38	4.21	1.62
Def. rate	1	111	−2.43	0.19	−0.59	0.51
	2	28	−1.07	0.01	−0.48	0.26
	3	35	−2.09	−0.03	−0.43	0.41
	4	9	−0.40	−0.10	−0.24	0.11

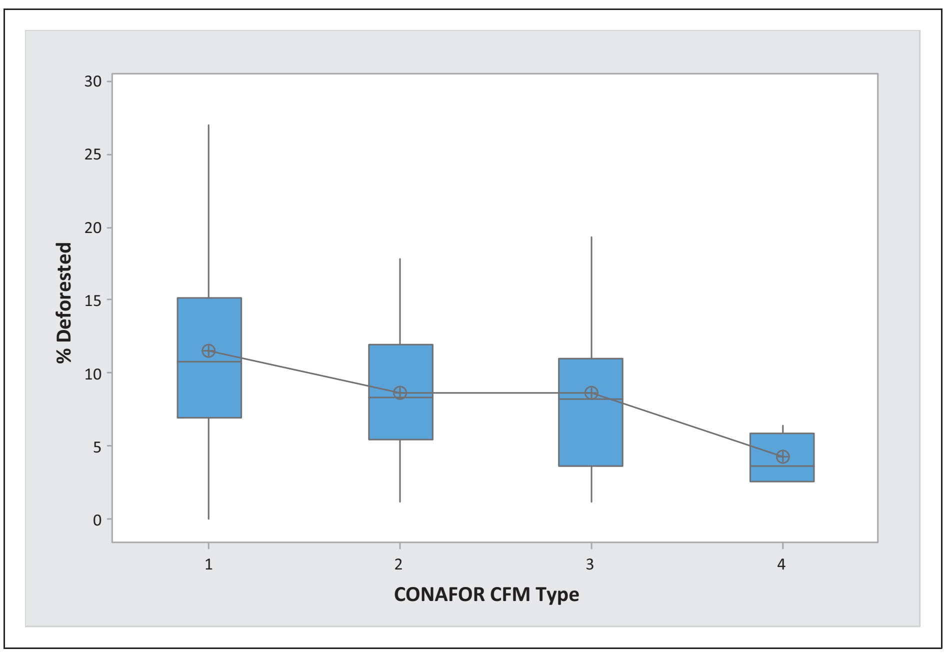

Figure 3. Comparison of means of loss of the forest coverage in ejidos with different types of forestry management according to the CONAFOR typology: Type 1, without CFM adoption but with forestry potential; Type 2, with CFM but only sale standing timber and do not participate in forestry operations; Type 3, with CFM that sale cut timber and participate in forestry operation; and Type 4, with sale of cut timber and lumber cut with their own sawmill and participate forestry operations.

ejidos which were also significantly different ($p = .026$; Figure 4). Type 4 ejidos have the lowest deforestation rates (mean = −0.24%), followed by Type 3 ejidos (mean = −0.43%), Type 2 ejidos (mean = −0.48%), and Type 1 ejidos (mean = −0.59%). However, pairwise comparisons only showed significant differences between Type 4 ejidos and Type 2 and Type 1 ejidos ($p = .048$ and $p = .094$, respectively).

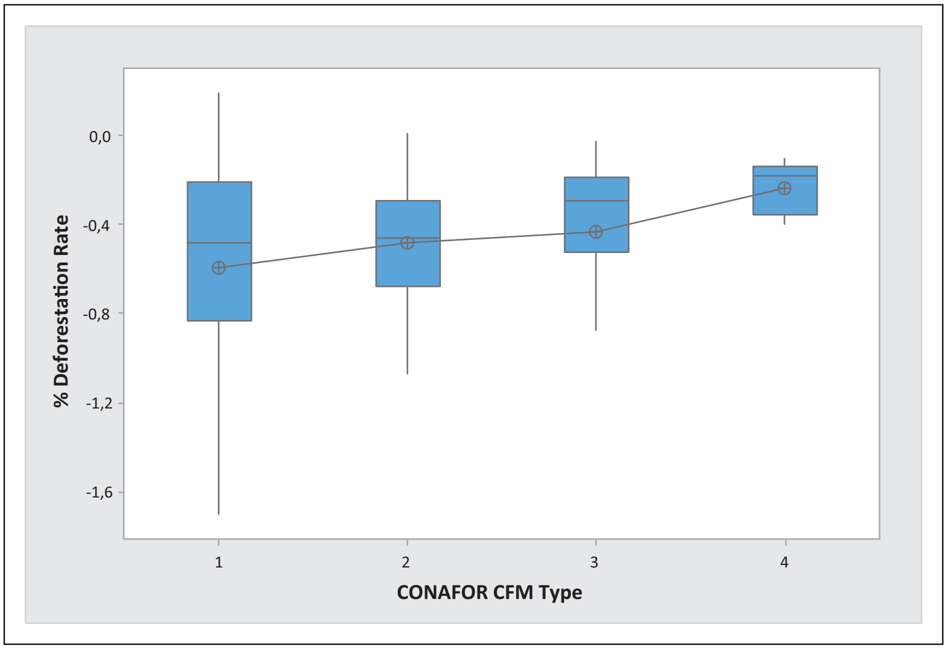

Figure 4. Comparison of means of the annual rate of loss of the forest coverage in ejidos with different types of forestry management according to the CONAFOR typology: Type 1 without CFM adoption but with forestry potential; Type 2, with CFM but only sale standing timber and do not participate in forestry operations; Type 3, with CFM that sale cut timber and participate in forestry operation; and Type 4, with sale of cut timber and lumber cut with their own sawmill and participate forestry operations.

Discussion

The results of the study show how heterogeneous and complex the processes of deforestation can be within the landscape of the Yucatán Peninsula. Some regions harbor low deforestation, such as conservation areas with PA or land use regions with CFM and milpa agriculture. However, other regions with commercial agricultural land uses such as sugarcane, maize, and livestock production are associated with rapid deforestation processes in the state of Quintana Roo. Moreover, regions with tourism and urban development are also responsible for recent deforestation in the state. Nevertheless, fire represented the major threat to recent forest cover loss in the state. Planning effective strategies to reduce deforestation and conserve biodiversity will need to consider all of these land uses and fire impacts in the landscape and their implications on deforestation processes and conservation in the state.

It is clear that, in order to reduce deforestation in the Yucatán Peninsula, in addition to PA and taking a land sparing approach, additional land sharing strategies must be implemented that promote the maintenance of forest coverage in areas of low deforestation threat, such as in CFM and Milpa land uses. In terms of biodiversity conservation, studies are finding that land sparing approaches in landscapes are more effective in conserving biodiversity than land sharing approaches (Chandler, Sohl, Jonas, Dowsett, & Kelley, 2013; Egan & Mortensen, 2012; Hulme et al., 2013). However, some of these authors also caution that it depends on the scale of the different land use systems studied and the regional crops and climate as well (Chandler et al., 2013), and that conservation strategies require careful land use planning (Hulme et al., 2013). Our results clearly show the potential of low input, milpa agriculture (a land sharing approach) in producing food and conserving forest cover in the state of Quintana Roo and the Yucatan Peninsula. Improving social welfare, while improving milpa production for local and regional markets in poorer and marginalized regions presents a new and important conservation and development challenge (CONAFOR, 2015).

Moreover, this study demonstrates that CFM in Quintana Roo, a land sharing approach, can also reduce the loss of forest cover compared with other commercial land uses, such as mechanized agriculture, sugarcane, and livestock, and even tourist infrastructure, which have much greater deforestation impacts in the region. In addition, our analysis comparing CFM type or degree of adoption and implementation shows that greater organization, investment, vertical integration, and community participation in forest management can produce favorable conditions for forest cover maintenance and biodiversity conservation and, in turn, provide greater economic benefits to those ejidos with CFM. Cubbage et al. (2015) have shown that community forest enterprises in Mexico are profitable and provide benefits to forest communities in Mexico. Deforestation pressures for obtaining income from forest conversion are reduced in forestry ejidos. This highlights the need to invest in strengthening the community forestry enterprises in the state of Quintana Roo as a potential production and conservation land use in the region.

Finally, land sparing strategies that reduce deforestation pressures in commercial agricultural regions, through increased intensification and production, will also be needed to ensure forest and biodiversity conservation in the state. However, the development of high-yield, intensive agricultural land uses will need to ensure environmental and social welfare protection (Hulme et al., 2013). The implementation of these high-yield systems in a sustainable and safe fashion will clearly be a development and conservation challenge in the region. Our results show that a combination of both land sparing and land sharing strategies would be optimal: that of integration of CFM and small scale agricultural systems, such as the milpa (land sharing), with a suitable implementation and management of PAs (land sparing), for the conservation of biodiversity in the tropical forest ecosystems in the Yucatán Peninsula. For that matter, the best solution may involve a middle route between these options, featuring protection and management of tropical forests alongside a shared use of these tropical ecosystems.

Implications for Conservation

Evaluating the processes and direct and underlying causes of regional forest cover change in relation to different land uses is essential in order to reduce deforestation for biodiversity conservation and climate change mitigation. This study shows how land sparing land uses such as high-yield and intensive mechanized agriculture or commercial maize and livestock production are associated with more deforestation than land sharing uses represented by milpa agriculture and CFM. Although land sparing strategies such as conserving quality habitat and forest cover with PA are effective in halting deforestation, integrating and combining sustainable land sharing strategies, particularly CFM, can complement biodiversity conservation in PA while providing economic benefits to local forest communities in the Yucatan Peninsula.

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