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Evaluation of forest cover loss in properties in the Sierra Madre Occidental, State of Durango, Mexico, certified by the Forest Stewardship Council

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ABSTRACT

Currently, most of the world's forests are governed by policies and regulations that contribute to sustainable forest management. The Forest Stewardship Council (FSC), a voluntary, non-governmental mechanism, proposes a market-based international certification scheme whose mission is to promote environmentally appropriate, socially beneficial and economically viable forest management. Despite the broad scope of the Principles and Criteria of this scheme, there is limited empirical evidence and a lack of rigorous evaluation in relation to the real impact on forest ecosystems. In order to generate evidence to contribute to the discussion, 42 properties (covering a total area of 1.1 Mill. ha) in northern Mexico, with and without FSC certification, were identified and evaluated in the period between 1986 and 2012. The results showed that there were no statistically significant differences ($p = 0.14$) in forest cover loss between certified and non-certified properties for the period before the properties joined this scheme. Similarly, for the nine-year period after certification, there were no significant differences ($p = 0.23$) between the two groups. This indicates that the certification scheme has not resulted in significant additional reductions in forest cover loss in certified forest areas. It is therefore important to review the standards imposed and the evaluation methods used in the scheme, in order to identify the real environmental impacts on forest resources and, if necessary, to implement rigorous and reliable methodologies, such as remote sensing tools, to continuously analyze the forest resource in the long term.

1. Introduction

Although the global net forest loss rate has decrease in recent decades, deforestation and degradation remain major problems, particularly in developing nations, and represent a threat to the conservation of all ecosystems (FAO and UNEP, 2020; FAO, 2020). Additionally, disturbances in forested areas can have negative impacts on socioeconomic well-being (Sousa, 1984; Manson and Jardel, 2009; Reyer et al., 2017).

In this context, the development and evolution of schemes aimed at forest management are taking place, hand in hand with an internationally oriented forest policy where countries agree on different points regarding forest management (El Lakany, 2017). Management grounded in sustainability principles, integrating ecological, economic and social issues as decisions led to the new paradigm of sustainable forest management (Gadow et al., 2001; Adamowicz and Burton, 2003). Currently, the great majority (96 %) of the world's forests is governed by policies and regulations that contribute to sustainable forest management (FAO and UNEP, 2020).

In addition to governments, non-governmental organizations have also attempted to develop guidelines for sustainable forest management. In this regard, an international mechanism emerged in the 1990s to address these issues. The Forest Stewardship Council (FSC), a pioneer in the field of forest certification, proposed the most influential and specific market-based certification standard for the sustainable use of forest resources (Auld et al., 2008; Karmann and Smith, 2009). The certified area currently exceeds 190,000,000 hectares (ha), encompassing more than 80 countries (https://fsc.org/en). The procedure for obtaining FSC certification is carried out by a qualified third party responsible for verifying that the forest management system complies with the established standards (Tamarit, 2003; Venegas, 2012).

The goal of the FSC is to promote environmentally appropriate, socially acceptable and economically viable management of the world's forests by establishing a set of principles and criteria (P&C) and indicators for assessing forest management (Romero et al., 2013; FSC, 2023). These specifications constitute an internationally recognized standard that contemplates an integral approach under the pillar of

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sustainability (economic, social and environmental) and they are related to aspects such as legal tenure, labour rights, community relations, efficient use of forest products and services, monitoring for evaluation of forest conditions and intensity of forest management (FSC, 2021).

This voluntary mechanism is in practice becoming a mandatory requirement for forest communities, with the promise of entering accessible markets and generating social, economic and environmental benefits (Meidinger, 2006; Muthoo, 2012). For some authors, it represents a valuable tool that stimulates the reactivation of community institutions and increased participatory governance, leading to positive changes in organizational capacities involving forest management (Rametsteiner and Simula, 2003; Taylor, 2005; Keskitalo et al., 2009; Moore et al., 2012).

However, over time some of the limitations in the implementation of FSC certification have become evident, such as those related to the generally high adaptation costs and the lack of market incentives as part of the fundamental objectives of this scheme, which do not translate into increased income for local communities. This has led to some communities losing interest in renewing their certificates or to question whether to continue with the certification process (Martínez and Colin, 2003; Tamarit, 2003; Gulbrandsen, 2004; Gerez-Fernandez and Alatorre--Guzman, 2007; Klooster, 2006; Blackman and Rivera, 2011). In addition to this, and despite the broad scope of the principles and criteria (P&C) and indicators managed by the FSC scheme, there is limited empirical evidence with rigorous evaluation regarding the real impact on forest ecosystems, particularly in terms of monitoring and assessing ecological functions and forest integrity (Gullison, 2003; Clark and Kozar, 2011; Romero et al., 2013; Angelstam et al., 2013; Blackman et al., 2017; Panlasigui et al., 2018).

Given that the main objective of FSC should be to reduce net deforestation, the lack of evidence hinders recognition of whether the certification mechanism contributes to fulfilling this goal. According to the most recent estimate of the annual rate of gross deforestation in Mexico for the period 2001–2018, deforestation affected an area of 79,672 hectares (ha) in 2001, then peaked at 350,298 ha in 2016 before decreasing to 166,337 ha in 2018 (CONAFOR, 2020). The state of Durango is the most important forestry region in Mexico, having timber reserves of about 90 m^3/ha on average (CONAFOR, 2018). Between 1986 and 2012, loss of forest area in Durango state, as estimated from satellite-based analysis, reached 34.2 % (an annual rate of 1.3 %), *i.e.* a loss of 32,840 hectares per year (Novo-Fernandez et al., 2018). Some of the records of greatest amount of forest cover loss are explained by natural events such as forest fires following severe droughts, as well as disturbance due to pests, such as borer insects, detected in 1997, 1999, 2010 and 2011.

Similarly, forest cover within the criteria established by FSC is not subject to continuous monitoring or evaluation, leading to a lack of knowledge about the dynamics of tree cover over time in FSC-certified properties.

In Mexico, this scheme is jointly implemented by the Rainforest Alliance (RA) and the Mexican Civil College for Sustainable Forestry, which was established in 1995. In this regard, certification has been supported and promoted by Non-Governmental Organizations (NGOs) and, since 2003, by the Mexican federal government. Currently, a total area of 1,437,692 hectares is currently certified under this scheme, ranking Mexico third among Latin American countries with this standard (https://fsc.org/en). However, this position of Mexico creates a paradox, since the expected economic incentives derived from international certification are apparently not generating any type of economic improvement in these communities, given that they are located in areas characterized by poverty and marginalization (Perez-Verdin, 2006; Merino, 2018; De la Federacion, 2020), which raises some doubts and sparks debate about the benefits to the forest communities belonging to this scheme and about the real impact of FSC (Gerez-Fernandez and Alatorre-Guzman, 2007). The state of Durango is currently the leader in terms of the number of certified properties, accounting for approximately 40 % of all certified forest properties in Mexico (https://fsc.org/en). The first FSC-certified property in the state of Durango was registered in 1997 (Martínez and Colin, 2003), and since then, 76 properties have been certified under the scheme.

Almost 30 years after its creation, the effectiveness of the forest certification system remains a topic of international forest policy debate. The extent to which the system is effective in ensuring sustainable management, especially in terms of environmental assessments, remains unclear (Auld et al., 2008).

Remote sensing techniques have become important tools for environmental and territorial analysis. This type of technology represents an area of opportunity, since the availability of satellite images provides an established, systematic, safe and easily accessible approach, in addition to allowing the evaluation of the impact on forest cover over time and the identification of changes in the landscape (Viana et al., 1996; Rametsteiner and Simula, 2003; Elbakidze et al., 2011; Romero et al., 2013; Pasquarella et al., 2016; Panlasigui et al., 2018; Molinier et al., 2021). As a result of this and as part of the new FSC monitoring and transparency initiatives, in 2019 a new tool was incorporated that allows access to geospatial information, to provide a better informed and effective audit process. However, despite this update in the international certification scheme, the mandatory use of this tool has not yet been standardized. Therefore, its effectiveness in audits is still scarce and its evidence in forest management certification evaluation reports is limited (https://fsc.org/en).

In accordance with the above, the present study aimed to identify and compare forested areas in ejidos, communities and private properties in the state of Durango, Mexico, with and without FSC certification in the period 1986–2012. Analysis of the satellite product derived from Landsat Time Series Stacks (LTSS) with the Vegetation Change Tracker (VCT) algorithm (Novo-Fernandez et al., 2018) enabled identification of changes in forest cover over time, with the aim of determining the impact of certification on forest cover. Considering this analysis, we question whether this international assessment system is a viable strategy for the conservation and protection of forests in Durango, Mexico.

2. Methods

2.1. Study area

The study was conducted in temperate forests in the Sierra Madre Occidental (SMO), Durango, Mexico (23°0′0'' N, 105°0′0'' W and 26°0′0'' N, 107°0′0''W). The SMO is a mountain range with one of the greatest richness of biological diversity in North America (Návar-Cháidez and Gonzalez-Elizondo, 2009).

Approximately 80 % of Mexico's forests are situated within ejidos and agrarian communities (the rest corresponds to private properties), which are characterized by their collective ownership structure. The main difference between these two types of collective forest management lies in when the land was granted to the community. This type of tenure entails that owners make collective decisions regarding forest management through various entities established to regulate the forest resources and services (Bray et al., 2007). In this study, ejidos, communities and private properties are referred to as "properties" to include all tenure types (Fig. A.1).

2.2. Selection of properties

All forestry properties in the state of Durango certified by the FSC were first identified. Properties certified between 1986 and 2012 and that have remained in the scheme continuously for at least nine years, *i.e.* almost two periods with the forest certification (5 years per period), were then identified. Properties certified under the scheme for less than nine years were not included because this was considered insufficient time to observe the impact of forest conservation and reforestation activities. Under the same conditions, non-FSC certified forest properties neighbouring to the previously selected properties were selected for study. This resulted in a total sample of 42 properties, of which 21 had FSC certification during the selected period, and 21 neighbouring properties did not have FSC certification (Table A.1).

2.3. Satellite image analysis

Novo-Fernández et al. (2018) used the Vegetation Change Tracker (VCT) algorithm (Huang et al., 2009) and Landsat Time Series Stacks (LTSS) to determine the spatial distribution of Forest Cover Loss (FCL) (Zhao et al., 2015) to spatial level resolution of 30 × 30 m per pixel in temperate forest ecosystems in the SMO of the state of Durango from 1986 to 2012. FCL can be defined here as the detection of a forest disturbance event (produced by *e.g.*, logging, fire or urban development), revealed by the VCT algorithm at pixel scale when the images indicate the presence of forest for two consecutive years before disturbance and non-forest for at least two consecutive years after disturbance (forest threshold for sparse forests). Therefore, a second disturbance, and thus a second FCL event, can only occur at least four years after the first (Zhao et al., 2015).

This spatial distribution of FCL formed the basis of our FCL analyses. FCL data were then extracted for each property in the study area. The procedure was carried out in ArcGIS 10.8 software, using the mask extraction tool (see details in Novo-Fernández et al., 2018).

2.4. Attribute selection

Following the acquisition of the property images tool (see details in Novo-Fernández et al., 2018), the attributes corresponding to FCL in the areas between 1986 and 2012 were identified for the 42 forest properties. Specific data were then obtained for each property to enable temporal comparison of FCL between the 21 FSC certified and 21 non-certified properties. This comparison included two time periods: the nine years prior to FSC certification, and the nine years after FSC certification began (the period was different for each property, depending on the date when the FSC certification began). Finally, the FSC-certified and neighbouring non-certified properties were compared in the periods before and after FSC certification.

2.5. Statistical analysis

The non-parametric Mann–Whitney *U* test was used to determine whether there were any important statistical differences between two groups (Mann and Whitney, 1947), *i.e.* to identify and confirm any significant differences in FCL between FSC and non-FSC properties for the period before certification and the period after the FSC label was first awarded.

The same test was used to determine any differences in FCL in the same property before and after FSC certification and for the neighbouring non-certified property during the same periods.

3. Results

3.1. Forest cover loss (FCL)

In the retrospective analysis of all properties in the nine-year period before the certified properties joined the scheme, there was little difference in FCL between most of the FSC-certified properties and the neighbouring non-certified properties. The following comparisons revealed the greatest differences in FCL between the certified and non-certified properties: se-fc *vs* ba-no; ci-fc *vs* ln-no; cc-fc *vs* sj-no; lc-fc *vs* b-no; and cv-fc *vs* lc-no, with differences of 31.3 %, 16.8 %, 14.8 %, 13.6 % and 13.3 %, respectively. The mean percentage loss was slightly higher in non-certified properties in the nine years (19 % *cf* 14 % for the FSC-certified properties) (Table A.2).

During the nine-year period of FSC certification, a decrease in FCL was observed in most of the certified and non-certified properties relative to the previous nine-year period. Additionally, there was a reduction in the difference in the percentage of FCL between the certified properties and the neighbouring non-certified properties. The properties for which differences were greatest were se-fc *vs* ba-no, cv-fc *vs* lc-no and md-fc *vs* ex-no, with percentages of 12.9 %, 9.3 %, and 8.7 % respectively. The percentage loss in the nine years was slightly higher in the non-certified properties: 10 % *vs* 7 % for the certified properties (Table A.3).

The certified properties where the highest percentage of forest cover loss occurred over the period considered were cc-fc, es-fc, md-fc, cv-fc and et-fc. The peak losses were recorded in 1997, 1999 and 2010. The es-fc property registered the highest percentage of FCL in 1997, with 15.7 %. Likewise, in the et-fc property a constant loss was observed between 1997 and 2010, unlike in the other properties, where a substantial decrease in FCL was recorded after 2000 (Fig. A.2).

In the neighbouring non-certified properties, *i.e.* ll-no, sj-no, ba-no, lc-no and es-no, significant peak losses also occurred in 1997 and 1999. The highest percentage FCL (22 %) occurred in the ll-no property in 1997. As observed in the certified properties with the highest FCL, there was a notable decrease in FCL in neighbouring properties after 2000, except in ba-no, where a constant loss was observed throughout the period considered (Fig. A.3).

Likewise, the certified properties with the lowest percentages of FCL throughout the period considered were lv-fc, ci-fc, sc-fc, lc-fc and ra-fc; the highest percentages of FCL occurred between 1996 and 1999 of 1.9 %, 1.1 %, 3.5 %, 2.7 % and 4.2 % respectively. Higher losses also occurred between 1996 and 1999 in the respective neighbouring non-certified properties: ar-no, ln-no, em-no, ba-no and lb-no. However, greater losses also occurred in ar-no and ba-no in 1997 than in the other properties (both certified and non-certified), with percentages of FCL of 12.7 % and 11.8 %. For both certified and non-certified properties, a notable decrease in the FCL was recorded from 2000, in the years when the beginning of certification was recorded for lv-fc, ci-fc, sc-fc, lc-fc and ra-fc, *i.e.*, in 2001, 2002, 2001, 2004 and 2002 respectively (Figs. A.4 and A.5).

In the comparisons between certified properties and non-certified neighbouring properties throughout the period considered, patterns of FCL were similar before and after the properties entered the FSC scheme, with the greatest losses occurring in 1997, 1999 and 2010, with a subsequent and notable period of decrease in losses between 2000 and 2009. However, differences were observed between some properties in some years: ra-fc *vs* lb-no, cc-fc *vs* sj-no, cv-fc *vs* lc-no, lv-fc *vs* ar-no and ci-fc *vs* ln-no (Figures S1–S21).

3.2. Mann–Whitney U test

The results of the Mann–Whitney *U* test comparing FSC-certified properties and neighbouring non-certified properties for the period before the certified properties joined the FSC scheme demonstrated that there were no statistically significant differences ($p = 0.137$) in FCL. Similarly, for the nine-year period after FSC certification, no statistically significant differences were observed in the two sets of properties ($p = 0.226$). Furthermore, the results of comparing the FCL between properties belonging to the FSC scheme before and after certification, as well as properties not belonging to this scheme in the same nine-year period, showed statistically significant differences ($p = 0.0002$ and $p = 0.0027$, respectively). In other words, while decreases in FCL were observed in FSC-certified properties, similar effects were observed as well on neighbouring non-certified properties. It was also recorded that the FCL was higher in the properties neighbouring the FSC-certified properties in the period before FSC certification (14 % FSC *vs* 12 % non-FSC). However, in the period after FSC certification began, the percentage FCL was higher in the FSC-certified properties (7.1 *vs* 6.2 %) (Table A.4).

The Mann–Whitney U test was also performed without the properties with the largest total surface area (Pueblo Nuevo and San Bernardino) as well as for their neighboring properties, which are not as large (Table A.1), and no significant changes were detected in the results.

4. Discussion

In the context of international certification and its primary objective of reversing degradation and deforestation, the adoption of best practices in forest management in different types of properties is expected to have significant effects, which should translate into a positive environmental impact. However, this study did not find any significant differences in FCL between certified and non-certified properties in the 9-year period after the FSC certification began. These findings are consistent with those reported by Nikolaeva et al. (2019), who used a similar geospatial analytical method to compare the percentage of FCL and gain in a region of Russia in three FSC-certified holders and three non-certified holders over a fifteen-year period. The results did not reveal any statistically significant differences in the percentage of FCL between these groups ($p = 0.90$), nor was there a significant difference in forest cover gain ($p = 0.36$). This also confirms that these rigorous, reliable methodologies are effective for determining the continuous and long-term impact of the schemes on forest properties. In this context, Goetz and Dubayah (2011) argue that forest monitoring using satellite imagery serves as an important basis for international agreements related to deforestation and other land use changes. With a systematic analysis with different indicators (living tree biomass and deadwood), but equally effective in comparing FSC-certified and non-certified areas in another region of Russia, Blumroeder et al. (2019) suggested that there were no significant differences between FSC-certified and non-certified forest management. Likewise, Villalobos et al. (2018) with data from the official forest inventory, estimated the effects of FSC certification on 53 forest properties in environmentally important areas in Sweden, observing that certified properties had a 3.7 % lower probability of non-compliance with forest management than non-certified properties. However, although the damaged area was smaller in certified properties, no substantial differences were detected, and therefore, no evidence was found that FSC certification contributes to reducing forest degradation in the country. Similarly, for the same period, Blackman et al. (2017) analyzed corrective action request data issued by auditors for 35 FSC-certified forest in Mexico, to determine the impact of FSC on deforestation. These researchers found that FSC certification did not lead to significant environmental benefits; instead, it primarily addressed minor procedural, social, economic and legal issues. They also emphasize the need for further comparative research between the performance of certified and non-certified forests, using field data and measurements. Our findings are also consistent with those of other studies carried out in Asia, Africa and South America (Panlasigui et al., 2015; Rana and Sills, 2018; Rico-Straffon, 2023).

In the present study, the highest values of FCL in certified and non-certified properties were closely related to natural events such as fires and forests pests in 1997 and 1999 (Quiñones, 2007) and to the extreme drought recorded in 2011, which began in 2010 (CONAFOR, 2012; Pompa-Garcia and Jurado, 2014). For the rest of the period considered, FCL was similar in both certified and non-certified properties (S1–S21). This is consistent with the findings of Miteva et al. (2015), who used temporal and spatial data on environmental indicators to compare certified and non-certified properties. Although these researchers were able to demonstrate a reduction in deforestation in certified properties, their findings regarding the occurrence of forest fires show that there was no statistically significant impact, *i.e.* certification did not have a positive impact on fire management.

Therefore, it could be argued that membership of FSC has not significantly improved the implementation of safety measures to reduce the impact of natural disasters and has not led to more active reforestation measures, such as planting trees after natural disasters. In fact, these post-disaster reforestation activities should be major contributors to measurable differences in FCL after a certain period of time, when they affect all forests in a region to a similar degree. Ryu et al. (2017) highlighted the important ecological functions of forests and the incentives they provide to residents who are negatively affected by damage due to natural disasters. These researchers also recognized the need for reforestation plans and strategies to restore areas affected by natural disasters. In this respect, Zhang (2019) evaluated and recognized the economic and environmental benefits of reforestation in his study, noting that the lack of a reforestation plan after a natural disaster can lead to forest degradation. Therefore, if appropriate reforestation assessment is not carried out after disturbance, the failure to reforest in a timely manner could lead to negative ecological and economic impacts. Stevens et al. (2021) also presented a framework for post-fire landscape management because of the environmental and social challenges associated with these heterogeneous burned landscapes. Therefore, post-fire decision-making should focus on adaptations to a warmer climate and future fire events. This includes modern spatial planning to optimize the success of reforestation.

Finally, despite the information accumulated, comparisons between areas or localities where this type of forest conservation policy has been developed may lead to biased estimates of causal impacts. Therefore, a rigorous methodology (including quasi-experimental techniques and using matching methods and multiple regression analysis) is proposed to enable selection of appropriate and comparable control groups to provide evidence of the causal impacts of the FSC programme (Miteva et al., 2015; Robalino et al., 2015; Romero et al., 2017).

5. Conclusion

We did not observe any statistically significant differences in FCL between certified and non-certified properties in forests in the SMO, state of Durango, Mexico, in the period between 1986 and 2012. Our results indicate that the environmental impacts of FSC certification are not yet visible in the forests in the state of Durango. One of the limitations of this study is the period considered, which spanned eighteen years (nine years before and nine years after certification), owing to the temporal range of the satellite images used for this study. Considering that the FSC system has been in place for thirty years, further studies using similar, effective and inexpensive methods, including a longer certification period, are needed for more accurate estimation of the impact of this international standard on forest properties. Successful attribution and ranking of factors influencing post-disaster reforestation efforts, both negatively and positively, may be helpful for regional forest managers. This would further bridge the gap between forest certification standards, field practices and follow-ups of these actions, through adequate feedback loops potentially also involving local communities. Further research beyond the scope of this study is needed to properly attribute and quantify these main factors.

CRediT authorship contribution statement

Aide Heredia-Telles: Investigation, Data curation, Formal analysis, Writing – original draft, Visualization. **Pablito M. López-Serrano:** Validation, Writing – review & editing. **Matthieu Molinier:** Validation, Writing – review & editing. **Christian Wehenkel:** Conceptualization, Resources, Writing – review & editing, Methodology, Project administration, Supervision, Validation.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Aide Heredia Telles reports was provided by Consejo Nacional de Humanidades, Ciencias y Tecnologia.

Data availability

Data will be made available on request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tfp.2023.100454.

Appendix

Table A.1
Properties with FSC certification (-fc) in the period 1986 to 2012 and neighbouring properties without FSC certification (-no).

FSC-certified property	Abbreviation	Type of tenure	Total area (ha)	Property non- certified by FSC	Abbreviation	Type of tenure	Total area (ha)
Vencedores y Anexos	ve-fc	Ejido	23,925	San Miguel de Cruces	sm-no	Ejido	4,207
La Manga y Anexos	lm-fc	Ejido	6,886	San Francisco de los Lobos	sf-no	Ejido	5,480
Compañía Silvícola Chapultepec	co-fc	Private	15,211	Las Pintas	lp-no	Private	6,085
Rancho Molinillos	ra-fc	Private	2,763	Las Bayas	lb-no	Private	4,691
San Isidro	si-fc	Ejido	7,354	El Regocijo	er-no	Ejido	7,022
Ciénega de los Caballos	cc-fc	Ejido	6,819	San Juan de Aguinaldo	sj-no	Ejido	3,002
Echeverría de la Sierra	es-fc	Ejido	5,327	Llano grande	ll-no	Ejido	10,946
Salto de Camellones	sc-fc	Ejido	12,793	El Metate	em-no	Communal	1,421
San Diego de Tezains	sd-fc	Ejido	61,087	Los Altares	la-no	Ejido	19,512
La Victoria	lv-fc	Ejido	10,646	Adolfo Ruiz Cortines	ar-no	Ejido	4,223
La Campana	lc-fc	Ejido	5,932	Barones	ba-no	Ejido	3,357
Pueblo Nuevo	pn-fc	Ejido	237,947	San Francisco de Lajas	fl-no	Communal	97,683
San Bernardino de Milpillas	sb-fc	Communal	153,202	Santa María Taxicaringa	mt-no	Communal	53,932
Chavarría Nuevo	cn-fc	Ejido	8,380	Los Bancos	lb-no	Ejido	3,666
Chavarría Viejo	cv-fc	Ejido	8,661	La Cueva y Anexos	lc-no	Ejido	10,646
El Brillante	eb-fc	Ejido	9,150	Antonio Molina Deras	am-no	Ejido	7,149
Mil Diez y anexos	md-fc	Ejido	4,943	El Salto	es-no	Ejido	1,664
San Esteban y Anexos	se_fc	Ejido	9,931	Banderas del Águila	ba-no	Ejido	10,272
San Pablo	sp-fc	Ejido	34,139	San José de Animas	sj-no	Ejido	12,462
La Ciudad	ci-fc	Ejido	13,323	Los Negros	ln-no	Ejido	4,365
El Tarahumar y Bajíos del T.	et-fc	Communal	73,310	Bagres y Anexos	ba-no	Communal	113,100
Total			711,729				384,885

Source: RAN, 2022; FSC, 2023.

Table A.2
Forest cover loss in FSC-certified properties and neighbouring non-certified properties in the 9-year period before FSC certification began.

FSC-certified property	Total forest area per property (ha)	Forest cover loss (FCL) (ha)	Total percentage FCL (%) in nine years	Property non-certified by FSC	Total forest area per property (ha)	Forest cover loss (FCL) (ha)	Total percentage (%) in nine years
ve-fc	16,149	1,736	10.7	sm-no	1,198	109	9.1
lm-fc	5,369	323	6.0	sf-no	3,178	442	13.9
co-fc	9,992	930	9.3	lp-no	4,038	475	11.8
ra-fc	2,438	228	9.4	lb-no	2,426	127	5.3
si-fc	5,784	895	15.5	er-no	11,010	1,967	17.9
cc-fc	3,585	866	24.2	sj-no	1,130	441	39.0
es-fc	2,678	707	26.4	ll-no	3,143	1,097	34.9
sc-fc	10,577	1,037	9.8	em-no	1,241	105	8.4
sd-fc	38,046	7,255	19.1	la-no	9,403	1,973	21.0
lv-fc	9,028	715	7.9	ar-no	1,678	398	23.7
lc-fc	3,977	375	9.4	ba-no	1,635	377	23.0
pn-fc	100,537	16,560	16.5	fl-no	38,310	6454	16.8
sb-fc	86,398	15,494	17.9	mt-no	27,662	4,557	16.5
cn-fc	5,825	677	11.6	lb-no	2,859	300	10.5
cv-fc	5,265	1,014	19.3	lc-no	8,838	526	6.0
eb-fc	7,307	753	10.3	am-no	4,322	546	12.6
md-fc	2,895	637	22	es-no	660	150	22.7
se_fc	4,241	824	19.4	ba-no	771	391	50.7
sp-fc	19,167	2,953	15.4	sj-no	3,453	765	22.1
ci-fc	10,355	394	3.8	ln-no	1,270	261	20.6
et-fc	36,114	6,583	18.2	ba-no	23,336	5,822	24.9
Total/mean	*385,728	**60,957	***14.3		*151,563	**27,282	***19.5

* Total forest area of all properties in the period before being certified by the Forest Stewardship Council.
** Total forest cover loss (ha) for all properties certified by the Forest Stewardship Council and neighbouring non-certified properties in the period before the certified properties joined the scheme.
*** Mean of the percentages forest cover loss relative to the total area of each property.

Table A.3
Forest cover loss in FSC-certified properties and neighbouring non-certified properties in the nine-year period after the properties were first certified.

FSC-certified property	Total forest area per property (ha)	Forest cover loss (FCL) (ha)	Total percentage (%) in nine years	Property non-certified by FSC	Total forest area per property (ha)	Forest cover loss (FCL) (ha)	Total percentage (%) in nine years
ve-fc	15,254	841	5.5	sm-no	1,141	51	4.4
lm-fc	5,207	161	3.1	sf-no	2,848	112	3.9
co-fc	9,611	548	5.7	lp-no	3,732	169	4.5
ra-fc	2,311	101	4.4	lb-no	2,438	139	5.7
si-fc	4,959	69	1.4	er-no	9,441	397	4.2
cc-fc	3,219	501	15.6	sj-no	791	102	12.8
es-fc	2,658	687	25.8	ll-no	2,733	686	25.1
sc-fc	9,630	89	0.9	em-no	1,151	15	1.3
sd-fc	33,239	2,449	7.4	la-no	8,431	1,001	11.9
lv-fc	8,500	188	2.2	ar-no	1,718	438	25.5
lc-fc	3,767	165	4.4	ba-no	1,394	136	9.7
pn-fc	85,511	1,533	1.8	fl-no	33,194	1,338	4.0
sb-fc	78,737	7,834	9.9	mt-no	25,604	2,499	9.8
cn-fc	5,736	589	10.3	lb-no	2,726	167	6.1
cv-fc	4,861	609	12.5	lc-no	8,587	274	3.2
eb-fc	6,999	4,456	6.4	am-no	4,051	276	6.8
md-fc	2,453	195	8.0	es-no	612	102	16.7
se_fc	3,600	183	5.1	ba-no	463	84	18.0
sp-fc	17,340	1,127	6.5	sj-no	2,904	216	7.4
ci-fc	10,253	291	2.8	ln-no	1,118	109	9.7
et-fc	35,588	6,056	17.0	ba-no	23,312	5,798	24.8
Total/mean	*349,433	**24,661	***7.5		*138,390	**14,108	***10.2

* Total forest area of all properties in the period before Forest Stewardship Council certification.
** Total forest cover loss (ha) for all FSC-certified properties and non-certified properties in the period after the certified properties joined the scheme.
*** Mean percentage (%) of forest cover loss relative to the total forest area of each FSC-certified property and non-certified properties in the period after the certified properties joined the scheme.

Table A.4
Differences in hectares and percentage and the Mann–Whitney U test results for comparison of Forest Stewardship Council (FSC)-certified properties and non-certified properties before and after certification.

	FSC-certified property (*C*)	Non-certified property (*D*)	Mann–Whitney U test
before FSC certification (*A*)	*866/**2,903 (ha)	*442/**1,300 (ha)	*C vs D of A* $p = 0.137$
***median (%)	11.85 %	14.06 %	
****mean (%)	15.80 %	18.00 %	
after FSC certification (B)	*501/**1,175 ha	*169/**672 ha	*C vs D of B* $p = 0.226$
***median (%)	7.15 %	6.18 %	
****mean (%)	7.05 %	10.19 %	
Mann-Whitney U Test	*A vs. B of C* $p = 0.0002$	*A vs. B of D* $p = 0.0027$	

* Median forest cover loss in all properties.
** Mean forest cover loss in all properties.
*** Percentage of the median forest cover loss.
**** Percentage of the mean forest cover loss for all properties. p = probability of similarity, (differences considered statistically significant at $p < 0.05$).

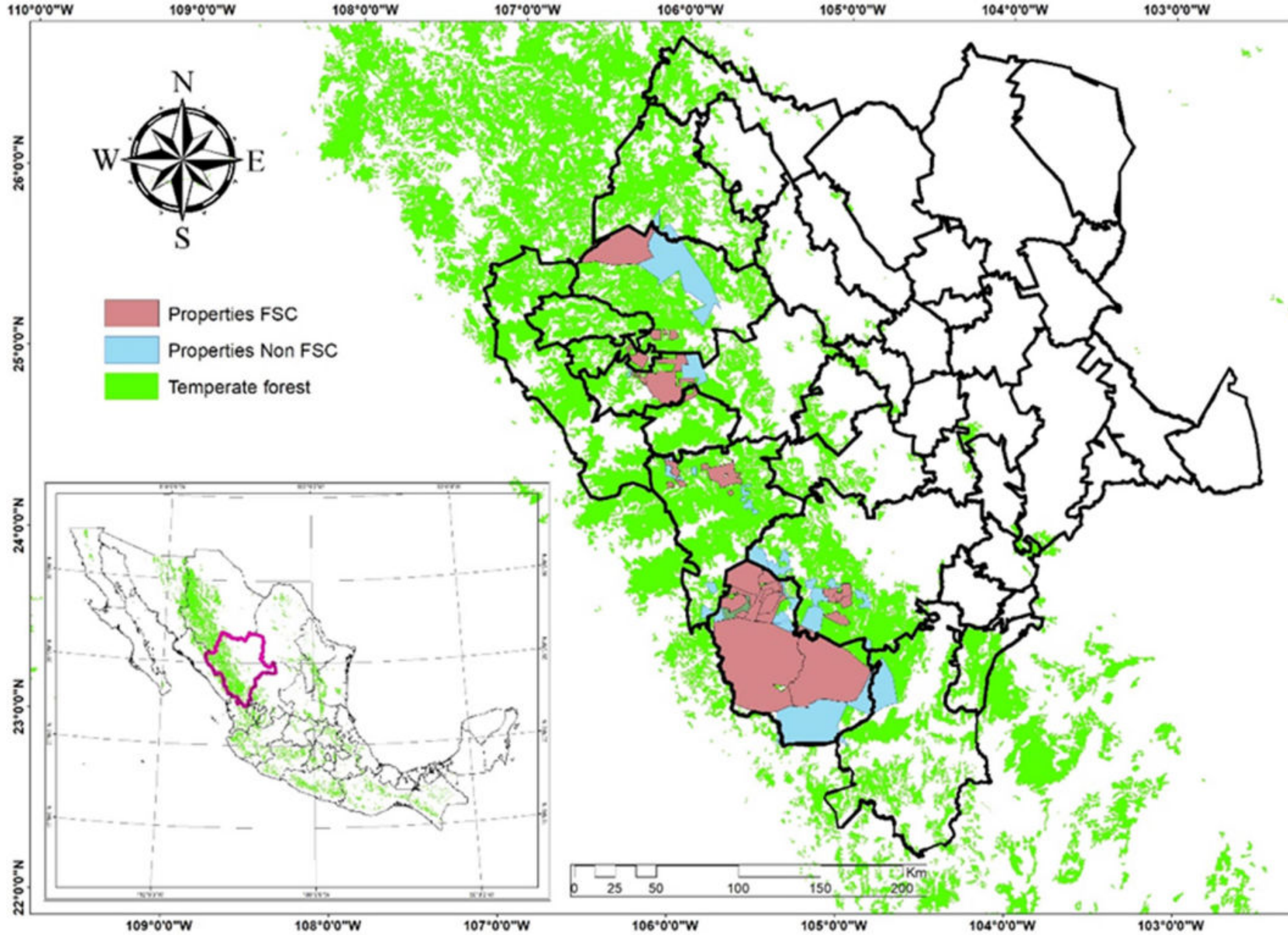

Fig. A.1. Location of 21 Forest Stewardship Council (FSC)-certified properties and 21 neighbouring non-certified properties in the period 1986–2012 in temperate forest, Durango, Mexico.

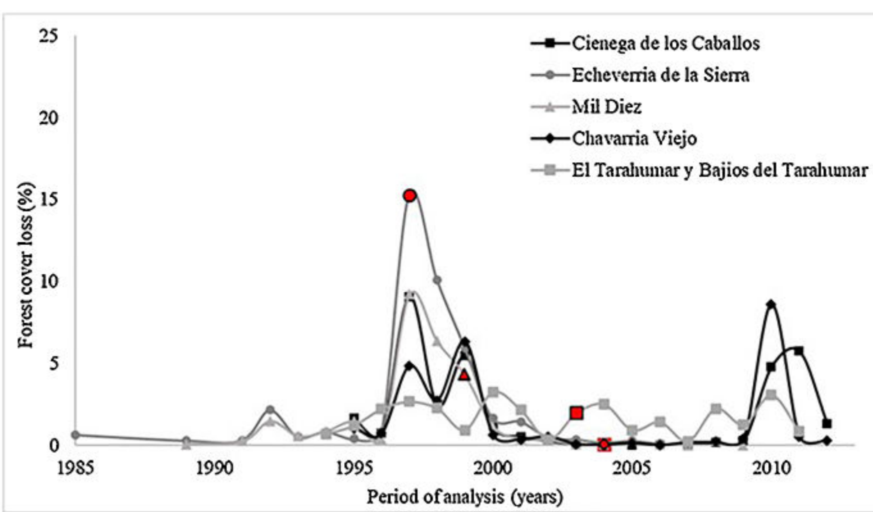

Fig. A.2. Comparison of forest cover loss (%) in the 9-year periods before and after Forest Stewardship Council certification of the certified properties with highest percentage of loss. Red symbols indicate the year certification began.

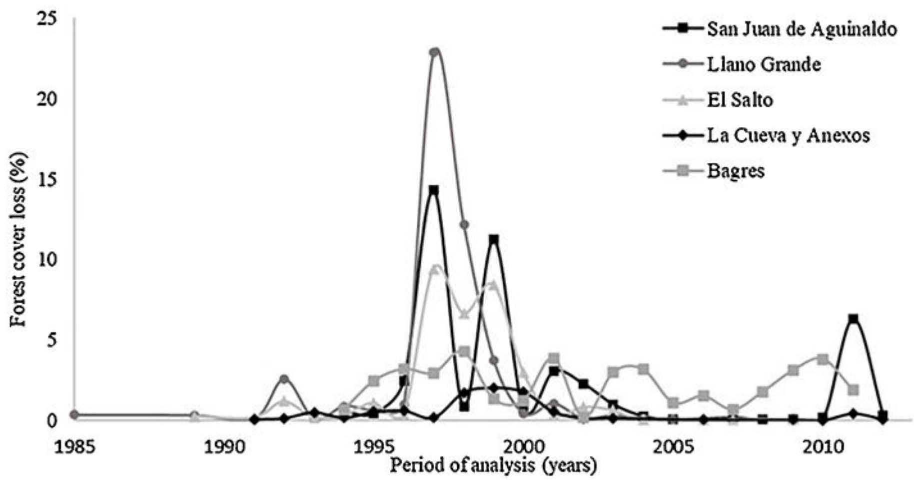

Fig. A.3. Comparison of forest cover loss (%) in the 9-year periods before and after Forest Stewardship Council certification of non-certified properties and neighbours of properties with highest percentage of loss.

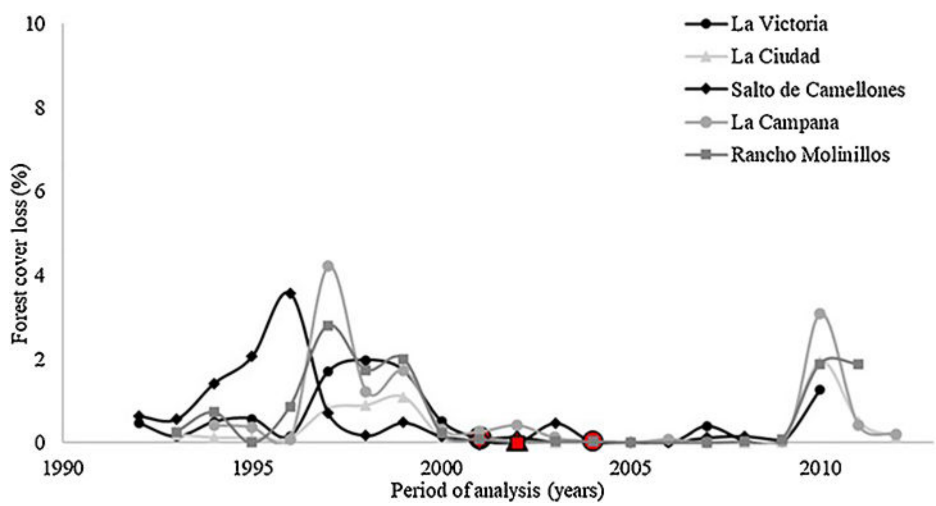

Fig. A.4. Comparison of forest cover loss (%) in the 9-year periods before and after Forest Stewardship Council certification of non-certified properties and neighbours of properties with lower percentage of loss. Red symbols indicate the year certification began.

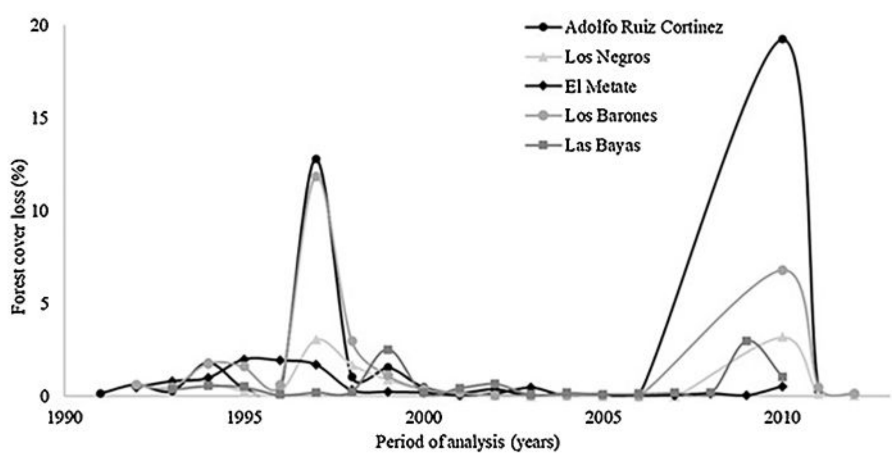

Fig. A.5. Comparison of forest cover loss (%) in the 9-year periods before and after Forest Stewardship Council certification of non-certified properties and neighbours of properties with lower percentage of loss.

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