Minimalist trends in Mexican tropical forest management: motives and experiences

Martin Alfonso Mendoza B.[1]
Angélica Navarro-Martínez[2]
Carl W. Mize[3]
Gerson Daniel Alducin Chávez[4]
Patricia Negreros-Castillo[5]

[1] Colegio de Postgraduados
Km 36.5 Carretera México-Texcoco
56230 Estado de México
México

[2] Observación y Estudio de la Tierra, la Atmosfera y el Océano
El Colegio de la Frontera Sur
Av. Centenario Km 5.5,
Pacto Obrero Campesino
CP 77014, Chetumal
Quintana Roo
México

[3] Iowa State University (retired)
Department of Natural Resource Ecology and Management
Ames, IA 50011
United States of America

[4] Instituto de Ecología A.C.
Carretera antigua a Coatepec 351
El Haya, AP 63
CP 91070, Xalapa Veracruz
México

[5] Academia Nacional de Ciencias Forestales
Calle Beta 109, Col. Romero de Terreros
Delegación Coyoacán
CP 04310, México
México

Auteur correspondant / Corresponding author:
Angélica NAVARRO-MARTÍNEZ – manava@ecosur.mx

Photo 1.
Riparian zone, example of forest conditions that justifies a specific treatment regime, as the other examples (photos 2).
Photo G. Galicia.

Doi : 10.19182/bft2021.348.a31913 – Droit d'auteur © 2021, Bois et Forêts des Tropiques – © Cirad – Date de soumission : 19 septembre 2020 ; date d'acceptation : 12 février 2021 ; date de publication : 18 juin 2021.

Citer l'article / To cite the article
Mendoza M. A. B., Navarro-Martínez A., Mize C. W., Alducin Chávez G. D., Negreros-Castillo P., 2021. Minimalist trends in Mexican tropical forest management: motives and experiences. Bois et Forêts des Tropiques, 348 : 29-36. Doi : https://doi.org/10.19182/bft2021.348.a31913

Bois et Forêts des Tropiques – ISSN: L-0006-579X
Volume 348 – 2nd quarter - June 2021 - p. 29-36
FOCUS / TROPICAL FOREST MANAGEMENT

RÉSUMÉ

Tendances minimalistes dans la gestion des forêts tropicales au Mexique : motivations et expériences

Les zones forestières tropicales de par le monde sont confrontées aux mêmes problèmes, tels que la dégradation et une régénération insuffisante suite à l'exploitation. La culture itinérante sur brûlis, mode de gestion traditionnel des Mayas, est aujourd'hui reconnue comme un moyen efficace de régénération des peuplements multi-espèces en zone forestière tropicale. La pratique des cultures sur brûlis au Mexique a donné lieu à une réglementation par zonage, si bien que la valeur du foncier est devenue un moyen commode pour évaluer différents plans d'exploitation forestière. En utilisant la valeur attendue du foncier comme indicateur de performance, le gestionnaire porte davantage son attention sur les arbitrages financiers entre la liquidation ou la rétention de la biomasse sur pied que sur la gestion d'un peuplement mixte. Le stock résiduel sur l'ensemble de la forêt étant très important, la valeur du foncier prime sur les revenus des ventes de bois. Plusieurs méthodes de gestion forestière allant dans ce sens sont apparues dans les régions tropicales du Mexique depuis une trentaine d'années, et représentent un mode de gestion patrimonial (GP). Le présent article décrit l'innovation générée peu à peu par ces modes de gestion, ainsi que des exemples de pratique en mode GP. Aujourd'hui, ces méthodes sont appliquées à la gestion de 155 814 ha au total dans différentes régions du Mexique. Leurs performances seront visibles à terme ; en attendant, l'adoption du mode GP par les propriétaires privés et les instances de réglementation est perçue comme un avis positif et indépendant sur la conception du mode GP. L'expérience mexicaine suggère des voies pour la gestion raisonnée de tous les types de forêts. Les éléments qui méritent réplication comprennent, par exemple, la prise en compte des formes de perturbation comme facteurs de décision, ainsi que l'adoption de régimes sylvicoles spécifiques pour les routes, zones boisées, forêts denses, sommets de colline, marécages, zones ripicoles, clairières et lisières.

Mots-clés : réglementation par zonage, valeur attendue du foncier, forêts mixtes, propriété forestière privée, culture sur brûlis, remplacement des peuplements, Mexique.

ABSTRACT

Minimalist trends in Mexican tropical forest management: motives and experiences

Tropical timber regions across the world share common problems such as degradation and poor regeneration after timber harvesting. Traditional Mayan land management through slash and burn is now recognized as an effective way of renewing forest stands in multispecies tropical forests. The practice of slash and burn for forest management in Mexico has led to area regulation, which has made land value a convenient means of assessing alternative forest plans. The use of expected land value as a performance indicator shifts the manager's attention from managing a species mix to balancing financial tradeoffs between liquidation or retention of the standing biomass. Since the forest-wide residual stock is so large, land value overrides the importance of revenue from timber sales. Several forest management methods along these lines have appeared in tropical regions of Mexico over a thirty-year time span and represent a Patrimonial System of forest management (PS). The gradual innovation generated by PS is described here, as well as examples of PS practices. PS methods today provide stewardship for a total of 155,814 ha in different parts of Mexico. PS performance will become evident in the long run; in the meantime, the embrace of PS by private landowners and regulatory institutions is equated with a positive, independent opinion about PS design. The Mexican experience suggests pathways for rational management of all types of forests. PS features that are worth replicating are, for instance, the inclusion of disturbance patterns as factors in decision making, as well as the use of specific silvicultural regimes for roads, woodlands, closed forests, hilltops, swamps, riparian zones, clearings and forest edges.

Keywords: area regulation, land value expectation, mixed forests, private timber forests, slash and burn, stand replacement, Mexico.

RESUMEN

Tendencias minimalistas en la gestión de los bosques tropicales mexicanos: motivaciones y experiencias

Las regiones tropicales madereras de todo el mundo comparten problemas comunes, como la degradación y la escasa regeneración tras el aprovechamiento maderero. La gestión tradicional maya de la tierra mediante roza, tumba y quema (RTQ) se reconoce ahora como una forma eficaz de renovar las masas forestales en los bosques tropicales multiespecies. La práctica de RTQ para la gestión forestal en México ha obligado a la regulación de la corta por superficie, lo que ha hecho que el valor de la tierra sea una herramienta conveniente para evaluar planes forestales alternativos. El uso del valor actual de la tierra como indicador de rendimiento desplaza la atención del gestor de la gestión de una mezcla de especies hacia balancear las conveniencias financieras entre la liquidación o la retención de la biomasa en pie. Dado que las existencias residuales del bosque son tan grandes, el valor de la tierra prevalece sobre los ingresos procedentes de la venta de madera. En las regiones tropicales de México han aparecido varios métodos de explotación forestal en este sentido. Ellos constituyen el sistema de ordenación forestal patrimonial (SP). Aquí se describe la innovación gradual generada por el SP, así como ejemplos de prácticas de SP. Hoy en día se aplican los métodos del SP para administrar un total de 155 814 hectáreas en diferentes zonas de México. El rendimiento de los SP será evidente a largo plazo; mientras tanto, la actual aceptación del SP por parte de los propietarios privados y las instituciones reguladoras se puede considerar que es una opinión independiente sobre el diseño del SP. Esta experiencia mexicana sugiere vías para la gestión racional para todo tipo de bosques. Las características del SP que merecen ser reproducidas son, por ejemplo: la inclusión de los patrones de perturbación como factores en la toma de decisiones, así como el uso de regímenes silvícolas específicos para caminos, arboledas, bosques cerrados, cumbres, humidales, riveras, claros y bosques de orilla.

Palabras clave: regulación por superficie, valor actual de la tierra, bosques mixtos, bosques madereros privados, roza, tumba y quema (RTQ), reemplazo del rodal, México.

Introduction

Systematic, planned forest harvesting in Mexican tropical timberlands started in 1954 (Diario Oficial de la Federación, 1954). The guiding vision was that large trees are senile and declining in vigor. Selective harvest of the larger trees proceeded at a slow pace with the expectation that younger, residual trees would eventually accrue new biomass exceeding the amount removed. These ideas about partial cutting and minimum cutting diameter have become unfeasible worldwide (Clément, 1997; Blaser *et al*., 2006; Sist *et al*., 2015).

The Patrimonial System of forest management (PS) offers an alternative to Mexican and international selective management by shifting to land stewardship goals on privately-owned tropical forests (Mendoza *et al*., 2021; Mendoza *et al*., 2021, in press). This new system comprises all the usual features of a temperate forest plan: silviculture, protection, harvest regulation, forest inventory, roads, and logging. Fundamental ideas in PS were gradually assembled, starting with Plan Costa (Mendoza *et al*., 2015) in 1980. Manejo de Paisajes (Landscape Management Method) started in 2002, and now it is near completion of the second cutting cycle (Mendoza *et al*. 2005). Método Silvícola Peninsular (Negreros-Castillo *et al*., 2018) is the newest component, the initial forest plans under MSP were in place by 2020. Today (2020) over 155,000 hectares are managed under the stewardship of PS concepts (table I). PS name is more than a common tag for several forest management methods that support the value of land as an indicator of performance and success. The Patrimonial System elicits the idea of patrimony as something of value that deserves responsible stewardship with, among other things, the intention to inherit. For most practical purposes, patrimony in this paper is akin to capitalization and equity.

The central argument in the classical Martin Faustmann's valuation formula means that the merits of a forest plan are better defined by the effects that such a policy has on land expectation value (Faustmann, 1849). The aim in this paper is to showcase PS as a new vision of timber management that revisits the old idea that timber management rests upon real estate management concepts. A rational decision-maker will consider assessing these effects in the context of other important decision criteria. This paper shows one possible way to design forest management upon the idea of harvest scheduling through area regulation of slash and burn silviculture. Complex tropical forests can be responsibly managed with simple rules for silviculture and harvest regulation.

Table I.
Ownerships that use patrimonial system management methods in 2020.

Tenure	Name	Location	Method	Status	Area Ha
Ejido	Kancabchen	Quintana Roo	Silvícola peninsular	Approved	13,310
Ejido	El Naranjal	Quintana Roo	Silvícola peninsular	Approved	8,292
Ejido	Candelaria II	Quintana Roo	Silvícola peninsular	Approved	5,407
Ejido	Lázaro Cárdenas	Quintana Roo	Silvícola peninsular	Approved	6,472
Ejido	La Esperanza	Quintana Roo	Silvícola peninsular	Submitted	8,206
Ejido	Los Lagartos	Quintana Roo	Silvícola peninsular	Submitted	5,323
Ejido	Dos Aguadas	Quintana Roo	Silvícola peninsular	Approved	5,593
Ejido	Almirante Othón P. Blanco	Quintana Roo	Silvícola peninsular	Approved	10,868
Ejido	Betania	Quintana Roo	Silvícola peninsular	Submitted	11,036
Ejido	Chan Santa Cruz	Quintana Roo	Silvícola peninsular	Submitted	6,540
Ejido	Tulum	Quintana Roo	Silvícola peninsular	Submitted	22,800
Ejido	San Juan de Dios	Quintana Roo	Silvícola peninsular	Submitted	4,000
Ejido	Profr. Graciano Sánchez	Quintana Roo	Silvícola peninsular	Submitted	4,000
Ejido	Centauro del Norte	Campeche	Plan costa	Approved	225
Ejido	Benito Juárez	Campeche	Plan costa	Approved	120
Ejido	Álvaro Obregón	Campeche	Plan costa	Approved	10,000
Ejido	Plan de San Luis	Campeche	Minimum diameter	Approved	5,000
Ejido	Nuevo Becal	Campeche	Minimum diameter	Approved	10,000
Easement	Nuevo Becal	Campeche	Silvícola peninsular	Submitted	5,500
Private	Llanito y 4 más	Jalisco	Manejo del paisaje	Approved	3,305
Private	Santa Bárbara y 10 más	Jalisco	Manejo del paisaje	Approved	5,650
Private	Bufa	Jalisco	Manejo del paisaje	Approved	656
Private	Atajo	Jalisco	Manejo del paisaje	Approved	3,511
Total					**155,814**

Bois et Forêts des Tropiques – ISSN: L-0006-579X
Volume 348 – 2nd quarter - June 2021 - p. 29-36
FOCUS / TROPICAL FOREST MANAGEMENT

Methods

This paper is a chronicle of a local innovation experience told from the perspective of the developers. As such, it is an exercise on self-reflection seeking to enclose all the essentials and those issues and concerns of international interest.

Sources of information consulted include publications on PS concepts (Navarro-Martínez *et al*., 2020). This book describes in detail concepts, methods, and parameters for all methods currently complying with PS. It also provides links to publications and materials related to PS. International issues and concerns addressed in PS are discussed in Negreros-Castillo *et al*. (2018).

PS is a recent creation, publications about its features are expected to reach the public in the near future. Even so, this paper's references already comprise the essential and most important elements of PS, and its position against all other forest management approaches.

Forest plans provided by practicing foresters, where consulted to provided evidence of PS practice. The value of land transactions was provided by Ruben Uu Chi (SESISA forestry consulting firm).

Results

This section starts with background factors that opened a window of opportunity for innovation in tropical forest management. The silvicultural features of slash and burn are then discussed as a response to historic trends. The next topic deals with how slash and burn fits into the simple harvest allocation schemes typical of area regulation. Only a small step is then needed to arrive at performance assessed through increased land expectation value. The paper closes with comments on the level of acceptance and practice of innovations proposed, and possible international relevance.

Local historic context

PS is a theoretical development. As such, it is expected to serve as a framework for forest plans anywhere; even so, PS has been specially tuned to the current Mexican scenario. The main features of Mexican forestry are shaped by the historic fact that all forest land is regulated by agrarian laws (Cámara de Diputados, 2018b). Public timberlands in Mexico are negligible, with some 3.9 % of the country being

Photos 2.
Other examples of forest conditions that justify a specific treatment regime.
a. Forest road. b. Edge vegetation and clearings. c. Forest interior. d. Slash and burn plot.
Photos M. Mendoza (a, b, c), P. Negreros (d).

public (Morett-Sánchez and Cosío-Ruiz, 2017). The mandate in the Mexican constitution (Cámara de Diputados, 2020b) can be interpreted as a need for timberlands to support landowners and other rural households. Also, wildlife law (Cámara de Diputados, 2018a) states that all wild creatures are public property. Similar laws claim public ownership of other natural resources, such as water (Cámara de Diputados, 2020a). These laws shape the legal framework for the practice of silviculture as a private business with a specific set of environmental responsibilities.

The international scenario shows some ten million hectares of tropical forests under planned forest management (Blaser *et al*., 2006). This is a significant amount of land whose management may benefit from the Mexican experience.

Silviculture

Although PS ecological success rests upon the multiple evidences of slash and burn efficacy (Ribeiro Filho *et al*., 2013), its design can also be thought of as an application of disturbance ecology as explained by Oliver and Larson (1996). The fundamental treatment in PS is the stand replacement. Stand replacement (Franklin *et al*., 2002) means near complete overstory removals over 0.5 to 6 hectares, with some degree of partial retention to secure ample ground with direct sunlight. At the same time, all microsites must be shaded part of the day. Legacy of structures retained from the previous stand (snags, litter, downed wood, small groups of live trees) provides a good seedbed to help in the prompt and healthy establishment of regeneration. Slash and burn is a common practice in the tropical forest of the world, and this practice can be considered a silvicultural treatment since the end result is a forest stand with an enriched species composition (Negreros-Castillo *et al*., 2003; Ebel, 2018).

Any area in the commercial forest is eligible for final cut and stand replacement, as long as the treatment adds to the total target for replacement. The treatment is more than a clearcut, since it requires certain minimal partial shade and legacies (Franklin *et al*., 2002). Market opportunities and convenience in logging engineering and logistics are the main drivers defining where and when to harvest. It is important to keep in mind that harvest allocation rules require that final cut areas must be surrounded by forested vegetation at all times. No adjacent cuts will be planned until the new stand has reached the overstory height. Exceptions to this policy include special environments, such as hilltops, roads, riparian vegetation, understocked stands, natural permanent openings, and their border vegetation (photos 1 & 2). These special scenarios each deserve their own silvicultural regime. A description of each of these regimes can be found at Negreros-Castillo *et al*. (2018) and Navarro-Martínez *et al*. (2020).

The silvicultural system in PS strives for a slow pace in stand conversion, meaning that annual operations impact a minimal amount of terrain. However, stands not harvested in an annual cutting block are eligible for partial cutting to release goal trees, trees of desirable species and form.

Annual cutting blocks form a cutting cycle of arbitrary duration; current plans use a 20-year cycle for land tracks between 3,000 and 30,000 hectares of productive timberland. This cycle is a continuation of previous forest plans; there is no particular reason to retain or to change it.

The recorded pattern of disturbances is expected to continue with similar probabilities of periodicity, severity, and extension. Instead of preventing damages, combating incidents, or restoring affected sites, parameters for disturbed places are updated in the forest data set so that their new condition plays a part in the treatment allocation procedures (Negreros-Castillo *et al*., 2018). Preventive treatments can be considered for places with high exposure to disturbances if their expected efficacy compensates for their costs and uncertainty. Hurricanes can be erratic, beyond any planning, but disturbances caused by wildfire can be prevented by keeping tabs on fuel loads and their geographic distribution. Firebreaks and prescribed burning are good examples of cost-effective measures that prevent losses and damages from wildfires.

This simple silviculture allows effective control of the stand and the forest, despite the very large number of species and the considerable site variability typical of tropical timberlands. Other silvicultural systems that use the knowledge available about individual species and sites are unlikely to arrive at a feasible management solution for the whole mix; by contrast, PS has shown that a tropical forest can be handled as mixtures of bundled species and sites. This approach to a collective identity of a mixture collates the individual species' behavior in a way that treatments for the total stand provide the needed habitat for each component, as long as individual species are fit for that environment. In large spaces, and in the long run, there will be plenty of suitable spots for each and every species in the mix.

The overall management policy comes down to a treatment protocol similar to traditional Maya slash and burn shifting agriculture (Diemont *et al*., 2006; Negreros-Castillo *et al*., 2014), which is known to provide rapid restocking of clearings with a mixture representative of the natural forest with an increased density of the most valuable species.

Figure 1 shows a summary of the planning process for PS methods. This road map of decisions marks the places where silvicultural decisions are used. The intended use of silviculture data sets quality requirements for its acquisition. The decision-making process starts with the forest owner providing the legal documentation about his property. The land classification depends on terrain and cover. Land classification and historic precedents give support to a choice of silvicultural system for each type of land. A stand is a piece of land with a given forest structure where a field technician may suggest a number of alternative treatments. Mathematical models describing theory and results from experimental plots forecast economic effects of alternative silvicultural treatments and dynamics after plausible disturbances. These forecasts provide entry data to a harvest regulation routine. Harvest allocation follows financial indicators to suggest a set of alternative plans for the forest owner to choose and present to government regulatory agencies.

Bois et Forêts des Tropiques – ISSN: L-0006-579X
Volume 348 – 2nd quarter - June 2021 - p. 29-36
FOCUS / TROPICAL FOREST MANAGEMENT

Forest management as a conversion process

PS strives for responsible management of forest-owner assets. Because land is the overwhelming component, forest plans drift towards the question of holding and improving current stocking or converting it to new, likely better stands. The longer the original timber is retained, the more the benefits of a redesigned forest are pushed into the future.

If current stocking conditions were in such a shape as to provide an outlook of significant future output flow of products and economic benefits, then the incentive would be for postponing any final harvest that initiates new stands, and vice versa. Should the new forest outpace the current forest performance, a faster conversion is in order.

A recollection of historic experiences in Mexico (Mendoza *et al*., 2015) shows that after a few entries, the forest usually attains the main design features drafted in forest plans, but the reality in the market and expectations among the general public glosses over that outcome and dismisses the effort and talent of foresters of the past. There is no reason to expect that today's foresters have a sounder image of the target future forest than their predecessors. The choice in PS then is to slowly build a diversified forest structure, and gradually move the stand structure and distribution towards what is known about the timberlands of the early 20th Century. This is a no-regrets strategy that might not maximize revenue or land value, but it surely will be closer to the long-term risk avoidance preferences of forest owners.

Valuation and planning strategy

Mexican agrarian law, among other policies, provides protection to landowners against the odds that the owner might lose his land in bad deals with investors or creditors. These protections end up imposing regulatory takings that function as disincentives for real estate trading in rural areas. Even though it is infrequent, the sale of land and the sale of partial property rights happens regularly. The value of these transactions is stable enough to serve as a benchmark for PS valuation. Currently, a typical piece of good timberland bears a price tag equivalent to 94 US dollars per hectare, as reported by SESISA. PS practice is expected to sustain and even improve this land value better than the previous management policy, and upend real growth in retirement funds (annual average of 7.2 %, after taxes, for the last 10 years).

The inexorable risky environment for timber production prompted PS silvicultural treatments to be low cost, high efficacy, and small scale by design. In forest plans now underway the conversion process is expected to last over 200 years so that the annual entries for stand replacement will be around 0.5% of the available productive land.

PS departs from current Mexican forest practices because of its emphasis on forest land as a fixed asset, usually the most valuable item on the timber growing balance sheet. PS dropped the usual Mexican reliance on timber sales as a performance indicator because the net sales revenue approach makes sense only for infinite or very long-time horizons.

The valuation approach in PS can be thought of as if a rational investor would raise capital, or borrow it, to acquire timberland with intention of establishing a permanent logging business that would use net revenues to pay off investors and creditors. The residual income after paying costs and capital would be considered the economic benefit of timber production. PS algorithms draft a path to provide a steady positive flow of those benefits.

This logic stands regardless of the means of land acquisition. Agrarian reform land grants, which resulted in the landowners receiving the land for free, might give a false impression that land has no value, but that way of thinking leads to inferior timber management decisions. For instance, large trees and overstocked stands common at the time of the earlier entries are perceived as profitable and renewable resources, without realizing the extreme amount of time that it took for that stocking to reach big timber dimensions. If a sensible alternative investment were taken as the fulcrum in the assessment of silviculture alternatives, then big timber and old growth become windfall profits that are perfectly feasible but unprofitable to repeat.

Retirement funds can be a sensible alternative investment for benchmarking purposes. Using retirement funds as an alternative investment to forest management provides a visualization that forest land might be considered a form of long-term investment whose main benefit could be to build up equity faster than the retirement fund. Measuring timber production performance against retirement fund rates helps the forest owner better understand his holding or cutting decisions, but it does not replace the traditional use of an alternative rate of investment like the social rate of return in the planning phase and sensitivity analysis.

Cash received from timber sales, after paying direct costs could be deposited in

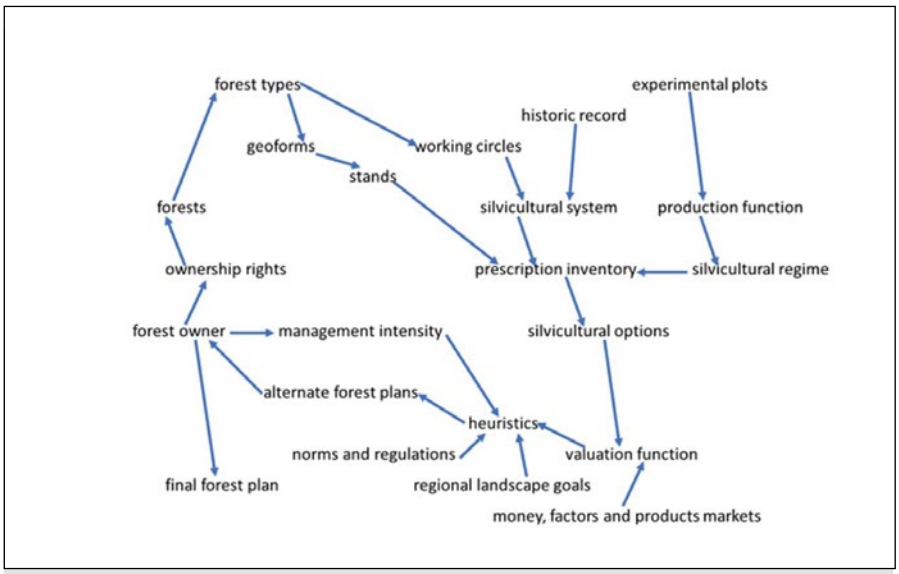

Figure 1.
Methodological flow chart for a forest plan that complies with PS standards.

financial investments as a way to park money until needed for silviculture practices, or to cover other forest management expenditures (González-Guillén *et al*., 1990). Such an arrangement creates the need to demonstrate that forest activities must offer benefits larger than the retirement fund, or else, the parked money would be better permanently committed to the retirement fund, growing faster and safer.

Capitalization of the retirement fund then could be converted to a periodic rent to support future needs, such as retirement and insurance coverage (medical, life, home, etc.) The level of future rents will depend on the initial size and value of forest land. For purposes of this paper, patrimony will be the value of forest land if sold at a given future time, plus the net value of any parked money, plus the current balance in the retirement fund. This vision widens the current expectation that the forest logging purpose is limited to providing wages and dividends.

Discussion

Management methods are seldom tested for performance. After their public release, they are put into practice. For the most part, long-term results are the outcome of the interplay between location, environment, technology, political and market dynamics. Accepting these limitations, an insight on the soundness of PS methods might be possible looking at landowners' adoption of these innovations. As of today (2020), PS comprises three management methods: Plan Costa (Apodaca-Martínez, 2014), Método Silvícola Peninsular (Negreros-Castillo *et al*., 2018), and Manejo de Paisajes Ecológicos (Mendoza *et al*., 2005). Other methods currently in practice have been modified to comply with PS criteria, for instance, minimum cutting diameter was adapted for secondary forest management in Calakmul, Campeche. PS management is practiced in Jalisco, Quintana Roo and Campeche (table I). Dissemination of PS ideas is underway to attract forest owners in other regions of Mexico. The total area reported in table I includes the complete ownerships because of PS oversight and goals encompassing every type of land beyond the actual area under timber production.

Public opinion about PS practice leans toward a concern that environmental impacts of stand replacement practices will lead to deforestation. This fear may simply express mistrust because PS is a major departure from selective cutting and volume regulation. These perceptions might improve later on, as soon as the prompt regeneration of harvested stands is observed.

Leadership at government institutions has expressed enthusiastic support for PS (Mendoza *et al*., 2019). Regulatory agencies have offered their support for several reasons. For one, tropical forest logging has been declining for a long time, so it is good that PS has been well taken by previously reluctant forest owners. Second, complex and unreliable volume regulation has been replaced with area regulation. This simplification increases accountability and norm compliance. Another reason is the prospect that PS may foster more of the current forests in the tropics to remain forested. Last, but not least, the economic needs of forest dwellers might be better secured by real alternate investments like retirement funds instead of reliance on labor wages, dividends from timber sales, or subsidies like payments for environmental services.

Conclusion

Landowners and regulatory institutions in Mexico have received with enthusiasm the Patrimonial System of forest management (PS) to guide forest plans for tropical timberlands. Current plans provide responsible stewardship to over 156,000 hectares in several tropical regions of Mexico. PS involves several forest management methods. Harvest regulation is area-based, and land expectation value is the merit criterion for alternative forest plans. A finite number of silvicultural treatments is available to manage mixed-species forests with a simple policy of retention or conversion of the current forest structure. In all methods, the final cut is a stand replacement procedure that follows traditional Mayan slash and burn. Experience shows slash and burn provide immediate restocking of natural regeneration at minimal expense. PS innovation means that only a few treatments are considered in a given harvest schedule, and simple rules for choosing cutting areas suffice to produce forest plans accepted by owners and government regulators. These tools have been successful in Mexico and they should be easily translated to forests in other countries.

Acknowledgements
We are grateful to the Sector Fund for Forestry Research, Development, and Innovation (CONACYT-CONAFOR) for financial support to project 292577 Design of a forest management system for productive forests in Mexico.

References

Apodaca-Martínez M., Curiel-Alcaraz G. M., Mendoza-Briseño M. A., Vargas-Mendoza M., Valdez-Hernández J. I., Platas-Rosado D. E., 2014. El plan costa como una mejor opción de manejo para especies forestales tropicales de Jalisco. Revista Mexicana de Ciencias Forestales, 5 (22): 10-25. https://cienciasforestales.inifap.gob.mx/editorial/index.php/forestales/article/view/347.

Blaser J., Poore D., Chandrasekaran C., Hirakuri S., 2006. Status of Tropical Forest Management 2005. Summary Report. International Forestry Review, 8 (3): 372-374. https://doi.org/10.1505/ifor.8.3.372.

Cámara de Diputados, 2018a. Ley General de Vida Silvestre. Diario Oficial de la Federación DOF 25-06-2018, 72 p. http://www.diputados.gob.mx/LeyesBiblio/ref/lgvs.htm

Cámara de Diputados, 2018b. Ley Agraria. Diario Oficial de la Federación DOF 19-01-2018. http://www.diputados.gob.mx/LeyesBiblio/ref/lagra/LAgra_ref14_25jun18.pdf

Cámara de Diputados, 2020a. Ley de Aguas Nacionales. Diario Oficial de la Federación DOF 06-01-2020. http://www.diputados.gob.mx/LeyesBiblio/ref/lan.htm.

Cámara de Diputados, 2020b. Constitución Política de los Estados Unidos Mexicanos. Diario Oficial de la Federación DOF 24-12-2020. http://www.diputados.gob.mx/LeyesBiblio/pdf_mov/Constitucion_Politica.pdf.

Clément J., 1997. Le développement de la pensée et des actions forestières tropicales depuis 1946. Bois et Forêts des Tropiques, 252 (2) : 5-24. https://revues.cirad.fr/index.php/BFT/article/view/19924.

Diario Oficial de la Federación, 1954. Decreto que establece una unidad industrial de explotación forestal a favor de Maderas Industrializadas de Quintana Roo, S. de R. L. en bosques nacionales y ejidales ubicados en la zona sur del Territorio de Quintana Roo. Secretaría de Agricultura y Ganadería, DOF 4 agosto 1954, 205 (30): 3-6. http://dof.gob.mx/index.php?year=1954&month=08&day=04,

Diemont S. A. W., Jay F. M., Levy S., Nigh R. B., Ramirez-Lopez P., Golicher D. J., 2006. Lacandon Maya forest management: Restoration of soil fertility using native tree species. Ecological Engineering 28 (3): 205-212. https://doi.org/10.1016/j.ecoleng.2005.10.012

Ebel R., 2018. Effects of Slash-and-Burn-Farming and a Fire-Free Management on a Cambisol in a Traditional Maya Farming System. CIENCIA ergo-sum, 25 (2). https://doi.org/10.30878/ces.v25n2a5

Faustmann M., 1849. On the Determination of the Value Which Forest Land and Immature Stands Possess for Forestry. *In*: Martin Faustmann and the evolution of discounted cash flow: two articles from the original German of 1849. W. Linnard (tr.) and M. Gane (ed.) (1968). Oxford, United Kingdom, University of Oxford, Commonwealth Forestry Institute, Paper No. 42. [Translation republished with permission from Commonwealth Forestry Association in Journal of Forest Economics 1: 1 (1995).]

Franklin J. F., Spies T. A., van Pelt A., Carey A. B., Thornburgh D. A., Berg D. R., *et al.*, 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. Forest Ecology and Management, 155: 399-423. https://ecoshare.info/uploads/ccamp/synthesis_paper_tools/Franklin_Spies_Van_Pelt_et_al._2002_Disturbances_and_structural_development_of_natural_forest_ecosystems_with_silvicultural_implications_using_PSME_forests_as_an_example.pdf.

González-Guillén M. J., Mendoza B. M. A., Bueno de Arjona G., Winter S. A., 1990. Representación de la empresa forestal en un sistema económico. Agrociencia, Serie Socioeconomía, 1 (1): 65-82.

Mendoza M. A., Fajardo J. J., Zepeta J., 2005. Manejo de paisaje, una interpretación práctica. Bois et Forêts des Tropiques, 285 (3): 47-54. https://revues.cirad.fr/index.php/BFT/article/view/20271

Mendoza M. A., Fajardo J. J., Curiel G., Domínguez F., Apodaca M., Rodríguez-Camarillo M. G., *et al.*, 2015. Harvest Regulation for Multi-Resource Management, Old and New Approaches (Old and New). Forests, 6: 670-691. https://doi.org/10.3390/f6030670

Mendoza M. A., Navarro-Martínez A., 2019. Del manejo forestal al manejo integrado del paisaje en México. Innovación Forestal, 19. https://www.conafor.gob.mx/innovacion_forestal/?p=6057.

Mendoza B. M. A., Navarro-Martínez A., Negreros-Castillo P., Uu-Chi R., 2021. Planeación del manejo forestal con fines patrimoniales. Madera y Bosques, 27 (1): e2712129. https://doi.org/10.21829/myb.2021.2712129

Mendoza Briseño M. A., Navarro-Martínez A., Negreros-Castillo P., del Ángel Santos D., 2021. Sistema patrimonial de manejo forestal para las selvas productivas de México. México, ECOSUR-CONAFOR, 192 p. *In press*.

Morett-Sánchez J. C., Cosío-Ruiz C., 2017. Panorama de los ejidos y comunidades agrarias en México. Agricultura, Sociedad y Desarrollo, 14 (1): 125-152. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1870-54722017000100125

Navarro-Martínez A., Mendoza-Briseño M. A., Negreros-Castillo P., Mallén-Rivera C., 2020. Selvas productivas de México. Retrospectiva de su dasonomía. San Cristóbal de Las Casas, Chiapas, México, El Colegio de la Frontera Sur, Comisión Nacional Forestal (MEX), 218 p.

Negreros-Castillo P., Snook L. K., Mize C. E., 2003. Regenerating mahogany (*Swietenia macrophylla*) from seed in Quintana Roo, Mexico: the effects of sowing method and clearing treatment. Forest Ecology and Management, 183: 351-362. https://doi.org/10.1016/S0378-1127(03)00143-9

Negreros-Castillo P., Cámara C. L., Deval M. S., Fajvan M. A., Mendoza B. M. A., Mize C. W., *et al.*, 2014. Silvicultura de las selvas de Caoba en Quintana Roo México: Criterios y recomendaciones (Silviculture of the mahogany forest of Quintana Roo, Mexico, Criteria and recommendations). Zapopan, Jalisco, México, Comisión Forestal para América del Norte, Organización de las Naciones Unidas para la Alimentación y la Agricultura, Comisión Nacional Forestal (MEX), Spanish and English, 188 p. https://doi.org/10.13140/RG.2.1.2813.5440

Negreros-Castillo P., Mendoza B. M. A., Navarro-Martínez A., Mize C. W., Cámara-Cabrales L., 2018. Peninsular Silvicultural Method. Slash and burn shifting agriculture means forest lands remain forested. International Forestry Working Group Newsletter, Society of American Foresters (in affiliation with the International Society of Tropical Foresters), 1-4. http://www.orrforest.net/saf/Sept2018.pdf.

Oliver C. D., Larson B. A., 1996. Forest Stand Dynamics. Update Edition. Yale School of the Environment Other Publications, 543 p. https://elischolar.library.yale.edu/fes_pubs/1

Ribeiro Filho A. A., Adams C., Sereni Murrieta R. S., 2013. The impacts of shifting cultivation on tropical forest soil: a review. Impactos da agricultura itinerante sobre o solo em florestas tropicais: uma revisão. Boletim do Museu Paraense Emílio Goeldi, Ciências Humanas, 8 (3): 693-727. https://doi.org/10.1590/S1981-81222013000300013

Sist P., Pacheco P., Nasi R., Blaser J., 2015. Management of natural tropical forests for the future. IUFRO WFSE Issue Brief 1/2015. https://www.researchgate.net/publication/275768866_Management_of_natural_tropical_forests_for_the_future.

Mendoza *et al.* – Author's contributions

Rôle du contributeur	Noms des auteurs
Conceptualization	M. A. Mendoza B., C. W. Mize, P. Negreros-Castillo
Formal Analysis	G. D. Alducin Chávez
Investigation	A. Navarro-Martínez, M. A. Mendoza B., G. D. Alducin Chávez
Methodology	M. A. Mendoza B., A. Navarro-Martínez, C. W. Mize, G. D. Alducin Chávez, P. Negreros-Castillo
Project Administration	A. Navarro-Martínez
Supervision	A. Navarro-Martínez, M. A. Mendoza B.
Validation	M. A. Mendoza B., G. D. Alducin Chávez, C. W. Mize
Visualization	A. Navarro-Martínez
Writing – Original Draft Preparation	M. A. Mendoza B., A. Navarro-Martínez, P. Negreros-Castillo
Writing – Review & Editing	M. A. Mendoza B., A. Navarro-Martínez, C. W. Mize, G. D. Alducin Chávez, P. Negreros-Castillo

Bois et Forêts des Tropiques - Revue scientifique du Cirad -

Cirad - Campus international de Baillarguet, 34398 Montpellier Cedex 5, France - Contact : bft@cirad.fr - ISSN : L-0006-579X