Revista Mexicana de Ciencias Forestales Vol. 13 (71)
Mayo - Junio (2022)

DOI: 10.29298/rmcf.v13i71.1142

Research Article

Productividad del abastecimiento e industrialización maderable en el ejido Aboreachi, Guachochi, Chihuahua

Supply productivity and timber industrialization in Aboreachi ejido, Guachochi, Chihuahua State

Joel Rascón-Solano[1], Óscar Alberto Aguirre-Calderón[2*], Eduardo Alanís-Rodríguez[2], Javier Jiménez-Pérez[2], Eduardo Javier Treviño-Garza[2], Juan Abel Nájera-Luna[3]

Fecha de recepción/Reception date: 15 de abril de 2021
Fecha de aceptación/Acceptance date: 4 de abril del 2022

[1]Programa de Doctorado en Ciencias con Orientación en Manejo de Recursos Naturales, Facultad de Ciencias Forestales, Universidad Autónoma de Nuevo León. México.
[2]Facultad de Ciencias Forestales, Universidad Autónoma de Nuevo León. México.
[3]División de Estudios de Posgrado e Investigación, Instituto Tecnológico de El Salto. México.
*Autor para correspondencia; correo-e: oscar.aguirrecl@uanl.edu.mx

Abstract

The objective of this research was to evaluate the productive evolution of a decade of timber supply, industrialization and commercialization in the *Aboreachi ejido*, *Guachochi*, *Chihuahua*. In this work, 10 annuities of timber harvesting were considered, from January 2010 to December 2019, 9 327 remissions of round wood and 2 040 reshipments of sawn wood were analyzed. The Shapiro-Wilks test was used to determine the normality of the observations; the homogeneity of the variances was determined with the Levene test; Kruskal-Wallis tests were carried out to evaluate the productivity of the annuities; and Pearson correlation analyzes were carried out to evaluate the increase in freight rates as a function of the authorized volume. All statistics were performed at a significance level α=0.05. Logging with draft animals increases jobs, but limits supply productivity in conjunction with the quality of vehicles. An increase in the number of shipments of round and sawn wood was found in relation to the increase in authorized volume (r=0.775 and 0.495 respectively). The Kruskal-Wallis analysis shows that the differences in round wood supply flows and supply expenditures were significant (α<0.05). On the other hand, the transport of sawn wood, processing expenses and sales income show significant differences (α<0.05) between annuities. The industrial technological renovation managed to increase the volumetric yield of sawn wood by 9.45 % and consequently the productivity of the *Aboreachi ejido*.

Key words: Harvesting, forest extraction, round wood, sawn wood, productivity, volumetric yield.

Resumen

El objetivo de esta investigación fue evaluar la evolución productiva de una década de abastecimiento, industrialización y comercialización maderable en el ejido Aboreachi, Guachochi, Chihuahua. Se consideraron 10 anualidades de aprovechamiento forestal maderable; de enero del año 2010 a diciembre de 2019 se analizaron 9 327 remisiones de madera en rollo y 2 040 reembarques de madera aserrada. La prueba de *Shapiro-Wilks* se usó para determinar la normalidad de las observaciones; la homogeneidad de las varianzas se determinó con la prueba de *Levene*; para evaluar la productividad de las anualidades se realizaron pruebas de *Kruskal-Wallis*, así como un análisis de correlación de *Pearson* para evaluar el incremento de los fletes en función del volumen autorizado. En todos los estadísticos se consideró un α=0.05. La extracción forestal con animales de tiro permite aumentar los puestos de trabajo, pero limita la productividad de abastecimiento en conjunto con la calidad de los vehículos. Se obtuvo un incremento en los fletes de madera en rollo y aserrada en relación con el aumento de volumen autorizado

(*r*=0.775 y 0.495, respectivamente). El análisis de *Kruskal-Wallis* mostró que las diferencias en los flujos de abastecimiento de madera en rollo y egresos de abastecimiento resultaron significativas (α<0.05). Por su parte, el transporte de madera aserrada, egresos de transformación e ingresos por venta presentaron diferencias significativas (α<0.05) entre anualidades. La renovación tecnológica industrial aumentó el rendimiento volumétrico de madera aserrada (9.45 %) y, por consiguiente, la productividad del ejido Aboreachi.

Palabras clave: Aprovechamiento, extracción, madera en rollo, madera aserrada, productividad, rendimiento volumétrico.

Introduction

Sustainable use in the extraction and transformation of products in forest communities seeks to reduce poverty and conserve ecosystems (Carrillo-Anzures *et al.*, 2017). The forests of Mexico provide goods and services to the population; timber resources have been, from an economic perspective, the most important asset over time (Caballero, 2017).

During the 2010-2017 period, the national timber forest production varied from 5.6 million cubic meters roll (m^3r) to 9.0 million m^3r, respectively, with an increase of 60.71 %; regarding the volumes of sawn wood for the last year, a production of 5.59 million cubic meters was registered, with an increase in the volume of 30.60 % compared to 2010 (Semarnat, 2011; Semarnat, 2020). Acuña-Carmona and Drake-Arana (2003) propose that given the growing trend of forest activity, constant monitoring of the resource is necessary, since decision-making must be based on a deep knowledge of use.

The sustainable management of forest resources involves choosing the most appropriate strategy for their use (Serrano-Ramírez *et al*., 2019). On the other hand, Marušák *et al.* (2015) indicate that forest resource managers determine the quantities and type of products generated that allow increasing the usefulness of the forest, without creating difficult dependencies that endanger the integrity of the ecosystems under harvesting (Pérez-Verín, 2006). Likewise, they have the challenge of defining

opportunities for improvement in forestry systems and forest operations (Aguirre-Calderón, 2015).

Within forest operations, the supply of raw materials and the shipment of products are distinguished (Rascón-Solano *et al.*, 2020), in which land transport is mostly used, due to its high versatility and variety of vehicles (Andalaft *et al.*, 2005) for the delivery of goods to processing centers and marketing points (Cranic and Laporte, 1997).

The objective of this contribution was to assess the productive evolution of a decade of timber supply, industrialization and commercialization in the *Aboreachi ejido*, *Guachochi*, *Chihuahua*, based on the assumption that the production indicators in each operation are in accordance with the technological reality and the economic potential of the *ejido*.

Materials and methods

Study area

The study was carried out in the *Aboreachi ejido*, located 56 km from the city of *Guachochi*; the largest population center in the *ejido* is called *Laguna de Aboreachi* (Rascón-Solano *et al.*, 2020), where the center for the transformation of timber raw materials is located and whose coordinates are 27°07'31.22" N and 107°18'05.35" W. The *ejido* has a harvested area of 10 946.18 ha, with an authorized volume of the *Pinus* genus of 181 423.62 cubic meters in total tree volume, distributed in 15 felling annuities.

Materials and Methods

In the analysis, 10 annuities of timber harvesting were considered, which included from January 2010 to December 2019. Since the *ejido* management program was updated in 2015, it was decided to record five annuities prior to that year and five after it. Additionally, within the selected period there were digital databases with the legal documentation corresponding to the supplies and reshipments of products.

To carry out the analysis and subsequent evaluation of the information regarding the supply of raw materials, 9 327 shipments of round wood were considered, in which the comparison factor was the annuity and as a variable the volume transported by truck with an 8-ton capacity, with intervals from 3.61 to 21.71 m^3r, cost of the raw material and number of freights carried out in each year of activity. The intervals of supply volumes between annuities were evaluated using quartiles (*Q1*, *Q2* and *Q3*), which made it possible to identify outliers or data entry errors, in which the first quartile (*Q1*) represents 25 %, the second quartile (*Q2* or median) 50 % and the third quartile (*Q3*) 75 % of the observations, sorted and divided into four equal parts.

In regard to the transformation of raw materials, 2 040 reshipments of sawn wood were analyzed, which included the transported volumes with intervals from 1.05 m^3 (retail sales) to 60.65 m^3 (wholesale sales), the cost of transformation and its market value in each year as variables to be evaluated, and annuities as a reference factor.

The supply and transformation flows of the *Pinus* genus were compared during the annuities from 2010 to 2019, in addition, the volumes of reshipments from the *ejido* in that period were counted. After that, the estimation of the transformation performance of the raw materials was made, based on the volumes of sawn wood as

a product and the shipments of sawdust and chips as solid waste. To this last concept the volume of non-waste marketed was added, and a productive comparison was made between the period when the *ejido* used band saw transformation equipment and the subsequent acquisition of a fine-cut sawmill. The purpose of this comparison was to determine if the technological transition had an effect on sawing productivity.

Statistical analysis

To test the normality hypothesis: *Ha*= the variables number of shipments of round wood, expenses generated by supply, sawn wood sales flow, transformation expenses and sawn wood marketing income have a different distribution than normal, used the Shapiro-Wilks test (α=0.05) by analyzing the values of kurtosis and asymmetry. The homogeneity of the variances of the variables was evaluated with the Levene test at a significance value of α=0.05.

The statistical differences were determined with a confidence interval of 95 % and a significance of 5 % through a Kruskal-Wallis analysis of the variables number of shipments of round wood, expenses generated by supply, flow of sawn wood sales, transformation expenditures and income from the sale of sawn wood based on the annual activity.

The Kruskal-Wallis H test was used to confirm whether there are statistical differences between the group intervals of a variable. Additionally, an analysis of Pearson's correlation coefficients (r) (α=0.05) was performed between the mean values per variable to evaluate whether the volume increases are related to the increase in freight rates per year. According to Martínez-González *et al.* (2006), the values of r=0 indicate no correlation between the variables, values of r <0.30 correspond to a

weak association, values of 0.30≤r≥0.70 represent a moderate association, and values of *r*>0.70 denote a strong correlation. Statistical analyzes were carried out with the InfoStat program 2018 version (Di Rienzo *et al*., 2018).

Results and Discussion

Descriptive and normality statistics of transport flows

According to the normality test of the variables, the Kurtosis Index and the asymmetry coefficient calculated were outside the statistical interval to consider them with a normal distribution (-2 and 2) (George and Mallery, 2010). On the other hand, the variance homogeneity test resulted in $p < 0.05$ values in all cases; because the variances between groups (annuities) did not present significant differences, the Kruskal-Wallis procedures from this database were considered to be valid at a significance level of <0.05 for productivity, expenses and income for the years included in the analysis.Table 1 shows the descriptive statistics, Kurtosis Index, asymmetry coefficient, factors analyzed and number of observations present in the study.

Table 1. Observations made for the supply and marketing of products in the *Aboreachi ejido*, *Guachochi* municipality, *Chihuahua*.

	95% of the confidence interval for the mean					
Year	**Upper limit (m^3r)**	**Minimum (m^3r)**	**Maximum (m^3r)**	***IC***	***CA***	***N***

	Authorized volume (m^3)	Mean (m^3r)	Std. Dev. (m^3r)	Lower limit (m^3r)						
Transport of *Pinus* spp. roundwood										
2010	8 428	9.47	0.06	9.36	9.59	6.46	16.71	2.57	1.72	888
2011	8 422	10.15	0.06	10.05	10.26	3.61	17.82	2.47	1.26	829
2012	8 479	9.51	0.05	9.41	9.60	4.86	16.16	2.53	1.08	889
2013	8 373	10.14	0.09	9.97	10.32	5.09	19.82	1.98	1.49	825
2014	8 399	9.96	0.09	9.78	10.14	6.18	19.63	1.95	1.55	843
2015	16 678	10.27	0.06	10.15	10.39	3.99	18.76	2.40	1.46	1 276
2016	13 490	10.50	0.09	10.31	10.68	5.12	20.30	0.31	1.19	1 002
2017	11 962	10.54	0.10	10.34	10.75	4.04	21.52	0.12	1.02	892
2018	11 888	10.57	0.13	10.32	10.83	4.81	21.71	0.56	1.40	881
2019	14 574	11.33	0.11	11.12	11.54	6.23	21.52	-0.29	0.93	1 002
Transport of *Pinus* spp. sawn wood										
2010	8 428	19.31	0.51	18.31	20.32	4.93	46.63	2.73	1.53	185
2011	8 422	23.22	0.73	21.77	24.67	3.53	44.32	-0.85	-0.14	164
2012	8 479	21.60	0.68	20.27	22.93	2.88	45.04	-0.27	0.42	180
2013	8 373	18.86	0.56	17.77	19.95	2.10	47.95	1.31	0.73	246
2014	8 399	25.77	0.96	23.88	27.67	2.11	54.98	-0.67	0.12	176
2015	16 678	26.12	0.75	24.63	27.60	1.56	60.18	-0.36	0.12	276
2016	13 490	26.26	0.92	24.45	28.08	1.12	60.65	-0.58	0.07	219
2017	11 962	24.91	0.89	23.15	26.67	1.05	59.71	-0.09	0.21	206
2018	11 888	29.71	1.04	27.65	31.77	2.61	57.47	-0.64	0.03	174
2019	14 574	29.60	1.16	27.31	31.90	1.16	59.42	-1.10	-0.13	214

*IC = Kurtosis index; CA = Asymmetry coefficient; N =: Number of freights made for roundwood and sawn wood.

Supply of *Pinus* spp. roundwood

In the *Aboreachi ejido*, pine log dragging and loading activities to a greater extent, are carried out with draft animals, which, according to what was cited by Bray *et al.* (2016), it is an alternative through which economic capital is distributed, in the form of wages, to a greater number of *ejidatarios*. In addition, it is an option that reduces the impact on residual trees, since mechanized extraction damages up to 48.00% of the remainder (Jackson *et al.,* 2002; Nájera-Luna *et al*., 2012). However, this technique is limited by the low load productivity in the vehicles that transport roundwood; in this regard, Nájera–Luna *et al.* (2011c) estimate that the mechanized load has yields between 19.83 and 35.27 m^3h^{-1} in the state of *Durango*, which is why it turns out to be more efficient, since it allows a higher product capacity, compared to the volumes registered in the *Aboreachi ejido*, which varied between 3.611 and 21.712 m^3r; with a higher load frequency (51.47 % of the total) whose values range from 8.72 to 10.95 m^3r (Figure 1).

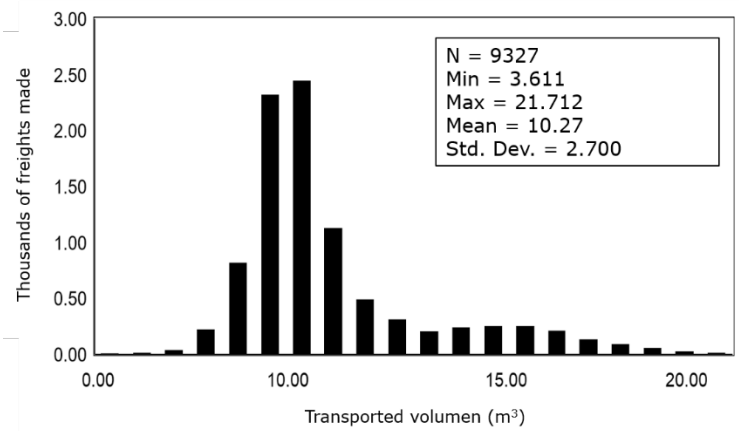


Figure 1. Frequency of the transported volume in 10 years of activity in the *Aboreachi ejido, Guachochi* municipality, *Chihuahua*.

Another factor that influenced the limited transport volumes is the type of vehicle available. Mainly, trucks with a 8 t capacity of the old model and in critical mechanical operating conditions were used; vehicles with a 15 t capacity were used to a lesser extent, under similar mechanical conditions. In relation to the above, the Association of Forest Professionals of *Oaxaca*, A. C. (CPFO, for its acronym in Spanish) (2015) indicates that the log supply system used in the *Sierra de Oaxaca* it coincides with those exposed in this study. The volumes transported by vehicles of 8 and 15 t correspond to 10 to 12 m^3r and 20 to 22 m^3r, respectively, load capacities similar to those registered in the *Aboreachi ejido*: 9.47 to 11.33 m^3r on average.

The foregoing is due to the fact that the extraction roads and supply routes in the aforementioned points of the Mexican Republic tend to be narrow and in poor condition that deteriorate the equipment, which makes it impossible for most of large dimensions transport vehicles to enter.

Figure 2 shows an increase in the total annual volume in 2015, which required a greater amount of roundwood shipments. This is due to the updating of the Forest Management Program of the *ejido* that allowed to increase the annual possibility of wood, in compliance with the objectives set by the National Strategy for Sustainable Forest Management to Increase Production and Productivity (Gómez-Puente, 2014; Enaipros, 2018).

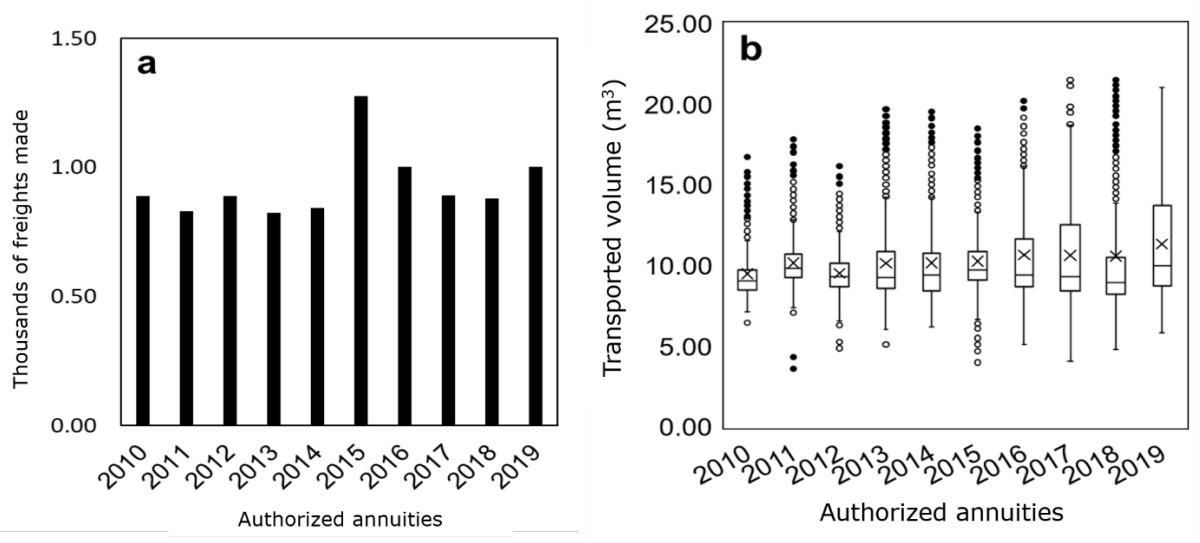


Figure 2. Annual comparison of the supply of logs in the *Aboreachi ejido*, *Guachochi* municipality, *Chihuahua*. a) Number of transports of raw material made each year; b) Box plot showing the distribution of the volumes observed in 10 annuities.

Based on Pearson's correlation analysis, an increase in the number of shipments was estimated in relation to the increase in authorized volume, with a value of r = 0.775. Since freight rates did not show a significant increase in transported volume, it was necessary to increase the number of loads per year.

The values displayed in graph b of Figure 2 indicate that the 2010 annuity concentrated a greater grouping in the observations analyzed between the first and third quartiles (*Q1-Q3*). The year 2018 has a higher proportion of outliers: freights that presented volumes greater than what is considered a grouped distribution based on the estimated average volume; while, the 2019 annuity had all the observations within the upper and lower intervals of the dispersion. It was shown that the mean of the observations with a greater adjustment around the median corresponded to 2012, with a difference of 0.22 m^3, and 2018 presented an average value outside the third interquartile; this last result is a deviation of the volume due to the effect of the large number of shipments that exceeded the volume ranges considered typical.

The information in Table 2 shows that the differences in roundwood supply flows were significant ($p \leq 0.05$). The highest transported volume was recorded in 2019, with an average of 11.33 m^3r. The year 2015 was the closest to the total average of the 10 annuities, with an average of 10.27 m^3r. On the other hand, the lowest average volume transported to the *ejido* transformation center corresponded to 2010, with a total of 9.47 m^3r; this annuity presented a high similarity in the average volume, compared to 2012 (9.51 m^3r).

Table 2. Conditions of the flows and supply costs in 10 annuities of extraction of the *Pinus* genus in the *Aboreachi ejido, Guachochi* municipality, *Chihuahua*.

Annuity	*N*	Means	Standard deviation	Standard error	Medians	Range average	*gl*	*H*	p	
Roundwood supply flow ($m^{-3}r$)										
2010	888	9.47	1.71	0.06	9.04	3 800.45	9	369	0.000	a
2012	889	9.51	1.44	0.05	9.29	4 258.16				a
2011	829	10.15	1.58	0.06	9.85	5 406.98				b
2013	825	10.14	2.60	0.09	9.24	4 490.98				b
2014	843	9.96	2.61	0.09	9.34	4 378.56				b
2015	1 276	10.27	2.19	0.06	9.74	5 127.12				bc
2018	881	10.57	3.85	0.13	8.92	4 060.66				bcd
2017	892	10.54	3.06	0.11	9.23	4 572.40				cd
2016	1 002	10.50	2.94	0.10	9.42	4 739.22				d
2019	1 002	11.33	3.39	0.11	9.96	5 504.32				e
Expenses generated in the supply ($ $m^{-3}r$)										
2010	888	4 053.31	732	0.06	3 867.22	2 585.83	9	1 444	0	a
2012	889	4 281.63	649.6	0.05	4 183.38	3 807.51				a
2011	829	4 343.46	678.03	0.06	4 213.73	4 013.91				b
2013	825	4 567.53	1 169.87	0.09	4 162.67	4 108.72				b
2014	843	4 484.64	1 175.33	0.09	4 205.90	3 980.80				b
2015	1 276	4 867.42	1 037.65	0.06	4 616.15	5 485.04				bc
2018	881	5 331.57	1 939.53	0.13	4 497.08	5 354.38				bd
2017	892	4 998.13	1 449.68	0.11	4 377.25	4 920.38				cd
2016	1 002	4 975.40	1 395.19	0.1	4 463.04	5 097.82				d

2019	1 002	5 715.46	1 708.56	0.11	5 023.54	6 520.84	e

*Average of the intervals with the same letter in each annuity are not significantly different according to the Kruskal-Wallis test ($p \leq 0.05$); *N* = Number of observations; *gl* = Degrees of freedom; *H* = Statistic test not corrected for ties; *p* = Significance value.

Regarding the number of shipments of round wood carried out, the year with the largest number of shipments was 2015, with 1 276 shipments, when also the highest volume of possibility of extraction recorded occurred; the year with the least amount of shipments was 2013 with 825, similar to 2011 with 829 deliveries made.

The variation between the volumes transported and the amount of freight carried is due to the capacity of the cargo vehicles (10 to 12 $m^{-3}r$ and 20 to 22 $m^{-3}r$), the availability of loading roundwood with mechanized equipment or draft animals, the quality of the extraction roads and the distances traveled to place the raw material in the transformation center, which vary from 500 m to 55 km. Additionally, the increase in profits obtained from freight, which according to Rascón-Solano *et al.* (2020) is $ 209.68 $m^{-3}r$, it encourages carriers to increase the volume of supply.

The expenses generated in the supply of raw material had significant differences ($p \leq 0.05$). The year 2010 registered the lowest flow of expenses, with $ 3 599 337.36, due to the fact that the possibility of use authorized for that year was lower; for this same year, the capital investment (total cost per freight) corresponded to an average of $ 4 053.31 delivered to the sawmill for the transportation of 9.47 $m^{-3}r$; and together with the year 2011, the investment was $ 427.79 $m^{-3}r$. The year that presented the highest flow of expenditures for the supply of pine roundwood was 2015, with $ 6 210 827.92 under the concept of total costs.

The year with the highest average distribution of dividends corresponded to the 2019 annuity, since the average volume of freight increased and the extraction and supply salary increased to $ 504.27 $m^{-3}r$. Expenditures coincide with that indicated by

Rascón-Solano *et al.* (2020), who estimate an average price of $ 482.27 $m^{-3}r$; however, they are lower compared to other studies developed in the region (Rascón-Solano *et al*., 2019a; Rascón-Solano *et al*., 2019b) in which extraction and supply costs of $ 889.83 $m^{-3}r$ and $ 1 101.69 $m^{-3}r$, respectively; on the other hand, the expenditures are higher, compared to the investment involved in the extraction in natural forests of Costa Rica for $ 115.44 $m^{-3}r$ (Navarro and Bermúdez, 2006).

Transformation of sawn wood from *Pinus* spp.

Table 3 shows that the differences in sawn wood sales flows are significant ($p \leq 0.05$). In 2010, the average volume of sawn wood sold (19.31 m^3) was lower than the averages of the rest of the years, with a standard deviation of ±6.94 m^3 transported. The highest average value of sawn wood transportation was recorded in 2018, with 29.71 m^3 and a standard deviation of ±13.78 m^3. In 2019, the standard deviation, with respect to the mean, was ±17.03 m^3, and it was the year with the lowest average value adjustment in the observations made. In regard to Pearson's correlation analysis, a relationship was observed between the increase in authorized timber volume and the number of sawn timber shipments carried out, with a value of r=0.495, which indicates a moderate positive association between the variables; this shows that the amount of transport to be carried out will increase, but given the variability of vehicles used in the activity, the increase will not present a slope similar to that of roundwood supply.

Table 3. Conditions of sales flows, expenses and income in 10 annuities of transformation of the *Pinus* genus in *Aboreachi ejido*, *Guachochi* municipality, *Chihuahua*.

Annuity	N	Means	Standard desviation	Standard error	Medians	Range average	gl	*H*	*p*	Annuity
Sawn wood sales flow (m^3)										
2010	185	19.31	6.94	0.51	16.46	736.52	9	174	0.001	a
2013	246	18.86	8.71	0.56	17.55	745.32				a
2012	180	21.6	9.06	0.68	19.84	885.64				ab
2011	164	23.22	9.39	0.73	24.79	981.89				b
2017	206	24.91	12.82	0.89	24.55	1 053.84				b
2014	176	25.77	12.74	0.96	27.19	1 093.30				bc
2015	276	26.12	12.54	0.75	26.71	1 121.97				bd
2016	219	26.26	13.63	0.92	26.33	1 118.82				be
2018	174	29.71	13.78	1.04	29.84	1 252.03				cde
2019	214	29.6	17.03	1.16	29.47	1 213.64				cde
Calculated expenses by sawing process ($ m^3)										
2010	185	4 987.78	1 793.40	132.5664	4 249.93	673.57	9	267	0.001	a
2013	246	5 021.50	2 318.34	147.8119	4 672.55	714.51				ac
2011	164	5 996.88	2 424.06	189.2871	6 402.78	905.99				b
2012	180	5 750.67	2 411.42	179.737	5 281.07	848.03				bc
2014	176	7 073.88	3 497.68	263.6477	7 464.21	1 078.53				cd
2015	276	7 168.34	3 441.00	207.1241	7 331.22	1 101.24				d
2016	219	7 587.73	3 939.15	266.1833	7 607.24	1 152.01				d
2017	206	7 196.35	3 703.56	258.0391	7 093.66	1 100.78				d
2018	174	9 035.36	4 189.89	317.6346	9 075.23	1 339.42				e
2019	214	9 003.96	5 180.14	354.1071	8 964.07	1 281.96				e
Obtained income from sawn wood sale ($ m^3)										
2010	185	57 321.05	20 610.23	1 523.49	48 841.41	706.47	9	216	0.000	a
2013	246	56 776.43	26 212.68	1 671.26	52 831.01	731.86				a
2012	180	64 105.11	26 881.16	2 003.60	58 870.28	851.97				ab
2011	164	68 917.90	27 857.98	2 175.34	73 582.66	946.95				b
2014	176	77 583.87	38 361.35	2 891.56	81 864.82	1 071.36				bc
2017	206	79 203.97	40 761.82	2 840.01	78 073.77	1 098.25				bc
2015	276	80 834.46	38 802.81	2 335.65	82 671.24	1 128.57				cd

2016	219	81 284.56	42 198.69	2 851.52	81 493.52	1 124.78	ce
2019	214	94 142.80	54 162.06	3 702.44	93 725.73	1 241.69	de
2018	174	94 471.17	43 808.26	3 321.10	94 888.02	1 287.94	e

*Average of the intervals with the same letter in each annuity are not significantly different according to the Kruskal-Wallis test ($p \leq 0.05$); N = Number of observations; *gl* = Degrees of freedom; *H* = Statistic test not corrected for ties; *p* = Significance value.

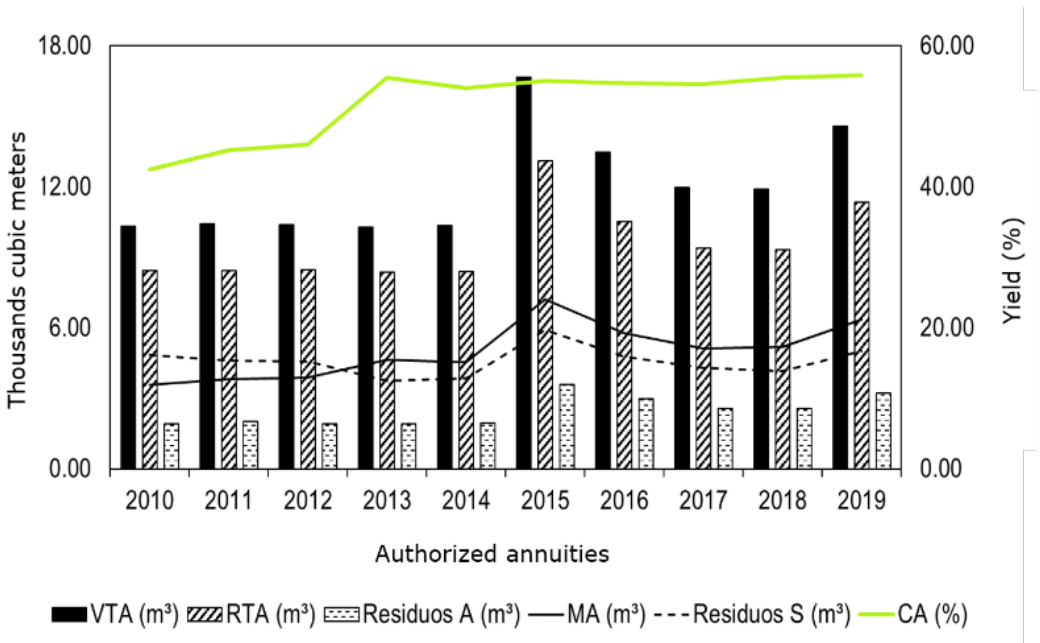
The calculated expenses of the annuities for the sawmill process reflected significant differences ($p \leq 0.05$), with a calculated average of 55.20 % higher for the year 2018, with respect to 2010, years that presented the highest and lowest average expense, respectively; the year 2015 required a higher unit investment, compared to the rest of the annuities, at an approximate cost of $ 0.65 per board foot (PT); the annuities with the highest cost per PT were 2018 and 2019, with an approximate investment of $ 0.72 per PT; Finally, the highest estimated expenditure was $ 922 883.69 for 2010, at a cost of $ 0.61 per PT. The difference in the volume of processed wood and the estimated transformation cost for each period influenced the result of the estimated expenditures.

The income obtained from the annuities for the sale of sawn wood, also resulted in significant differences ($p \leq 0.05$). 2018 registered the highest economic increase in all annuities, compared to 2013 (lower income) with 60.01 % less. During 2015, a capital income of $22 306 953.20 was obtained, under the concept of sawn wood sales, contrary to the 2010 annuity, which presented a gross profit of $ 10 606 053.60, for which the annuity income was lower. In 2017, 2018 and 2019, wood was offered at $ 7.50 per PT mill run, and in 2010, 2011 and 2012, the price was $ 7.00 per PT mill run, values that with sawing performance and production volume affected the obtained income. Likewise, these results indicate a growth in the price of wood, which

is related to the rise in prices of the inputs required for its transformation and with an increase in the demand for the products.

Comparison of supply and transformation flows

Figure 3 shows the flows of the process of supplying and marketing sawn timber of the *Pinus* genus during the period from 2010 to 2019. It is possible to identify the existence of variations in the harvest volumes of all the annual payments; on the contrary, the total tree roll volumes presented a constant proportion with respect to the total tree volume. The same is observed in the residual of the exploitation, because the extraction permits consider an approximate of 15.00 % under the concept of "waste".



VTA = Total Tree Volume; RTA: Total Tree Roll; Residuos A = Hatvesting wastes; MA = Sawn Wood; Residuos S= Solid Waste; CA = Sawing Coefficient.

Figure 3. Comparison of the flows of raw materials, products, waste and transformation yields of 10 annuities studied.

Regarding the volumes obtained by the transformation process, it was shown that the type of industry had an effect on the proportion of sawn wood and solid waste generated. In the *Aboreachi ejido*, a change of sawn wood transformation equipment was carried out, which included the adoption of machinery with the capacity to saw up to 16 000 PT per eight-hour shift; the cutting equipment is provided with 1.1 mm thick belts. Since 2013, the year in which the modern sawmill industry began its activity, based upon this modification, the sawn wood volume increased with respect to the waste generated. In addition, the acquisition of technology generated an effect on the average annual yield calculated through reshipments and remissions used in the *Aboreachi ejido*; it was possible to improve the sawmill yield by 9.45% from 2012 to 2013. Apparently, the average productivity has remained constant according to the logs of roundwood inputs and square-shaped wood outputs.

The products generated in the sawmill center of the *Aboreachi ejido* corresponded to sawn wood of the following thicknesses: 7/8, 5/4 and 6/4 inches; regarding the widths produced, the following were recorded: 4, 6, 8, 10 and 12 inches; in regard to the length of the generated tables, the dimensions were: 4, 6, 8, 10, 12, 14, 16 feet, and sometimes by special request: 18, 20 and 24 feet. Leyva *et al.* (2017), Ortiz *et al.* (2016) and Nájera-Luna *et al.* (2011b) cite similar measures in sawmills in the states of *Oaxaca* and *Durango*; these types of products are the most frequent and in greatest demand in the sawn wood market throughout the country.

Even though the records of the flow of supply and transformation indicate that the production and productivity of sawn wood have increased over the years, it is necessary to directly assess the transformation of products and determine the veracity of this information, since the estimation of the sawn wood yield was determined based on the supply flows of round wood (remissions), in which a sawmill coefficient of 51.87 % was estimated, with an interval of 42.47 to 55.79 % (the volume was considered in the calculation of bark).

Nájera-Luna *et al*. (2011a) and Nájera *et al.* (2011b) indicate yields in traditional industries in the region of *El Salto*, *Durango* of 57.50 %; Zavala-Zavala and Hernández-Cortés (2000) estimated a yield of 51.00 %; and Orozco-Contreras *et al.* (2016) 47.47 % average in different pine species. As for industries with fine-cut tapes, in a yield study in the *Paraná* region, Brazil, a sawmilling coefficient of 66.00 % was obtained in *Pinus ellioti* Engelm logs. with a portable sawmill prototype (Esteves-Magalhães *et al.*, 2010). For their part, Murara-Junior *et al.* (2013) obtained yields of 52.14 % with the use of 1.1 mm thick tapes, and a saw of a caliber similar to the one currently used in the *Aborachi ejido*.

Conclusions

During the 10 years analyzed, years of high and low possibility of harvesting pine wood are identified, which causes a variation in the number of freights carried out to execute the supply activities. According to Pearson's correlation analysis (r=0.775), there is an increase in the number of freights in relation to the increase in authorized volume; however, the authorized volume does not affect the average volume

transported by vehicles. The Kruskal-Wallis test shows that the differences in roundwood supply flows are significant (p=0.000) with mean intervals of 9.47 to 11.33 m^3r transported. The variability of the volumes transported and the increase in the costs of extraction and supply over 10 years cause the expenses related to the raw material to present significant differences (p=0.000); however, the average expenditure tends to be homogeneous in the first five years of activity, mainly due to the stability of the authorized volumes.

Regarding the freights involved in the transport of sawn wood, there are significant differences (p=0.001) in the average volume transported. Pearson's correlation analysis indicates a positive relationship between the increase in authorized timber volume and the increase in the number of sawn timber shipments made, with a value of r=0.495.

The estimated expenditures of the annuities for the sawmill process reflect significant differences (p=0.001). In this same sense, the year with the highest cost is 2019 with an approximate investment of $0.72 per PT, this is due to the annual increase in wages and payment for services involved in the timber transformation process. On the other hand, the income obtained from the sale of sawn wood in the annuities, also resulted in significant differences (p=0.000). The 2018 period records the greatest economic increase in all annuities; in comparison, the year 2013 (lower income) is 60.01 % lower.

It is evident that the volumes harvested, the constant increase in costs and the increase in the price of sawn products are variables that influence the average income from freight in the *Aboreachi ejido*. Finally, the increase in the annual timber production capacity and the acquisition of modern sawing equipment allow this *ejido* company to increase its productivity; since the industrial technological change increases the volumetric yield of sawn wood by 9.45 % from 2012 to 2013, from this year the yield tends to be constant.

This study highlights the importance of maintaining constant monitoring of the activities carried out in forestry companies in production. The evaluation of the supply volumes of raw materials and the products obtained in the subsequent transformation allows natural resource management bodies to know the actions carried out by forest producers. Additionally, it is proposed as a useful tool in the forest certification process.

Acknowledgements

The authors wish to thank the *Consejo Nacional de Ciencia y Tecnología* (National Science and Technology Council) for financing, through a scholarship from the first author's Doctorate of Science in Natural Resource Management studies. Additionally, the authors thank the anonymous reviewers, who with their suggestions contributed to improve the quality of this article.

Conflicts of interest

The authors declare no conflict of interest.

Contribution by author

Joel Rascón-Solano: data processing and analysis and writing of the manuscript; Oscar Alberto Aguirre Calderón: analysis of results, editing and review of the manuscript; Eduardo Alanís Rodríguez, Javier Jiménez Pérez and Eduardo Javier Treviño Garza: review and correction of the manuscript; Juan Abel Nájera Luna: review of the manuscript and discussion of results.

References

Acuña-Carmona, E. y F. Drake-Arana. 2003. Análisis del riesgo en la gestión forestal e inversiones silviculturales: una revisión bibliográfica. Bosque 24(1):113-124. Doi: 10.4067/S0717-92002003000100009.

Aguirre-Calderón, O. A. 2015. Manejo forestal en el siglo XXI. Madera y Bosques, 21(Especial):17-28. Doi: 10.21829/myb.2015.210423.

Andalaft, A., R. Landeros B. y J. Perret C. 2005. Caracterización de la industria de servicios de transporte forestal en Chile y estrategias competitivas de las firmas. Bosque (26)3:137-148. Doi: 10.4067/S0717-92002005000300016.

Bray, D., E. Durán, J. Hernández-Salas, C. Luján-Álvarez, M. Olivas-García and I. Grijalva-Martínez. 2016. Back to the Future: The Persistence of Horse Skidding in Large Scale Industrial Community Forests in Chihuahua, Mexico. Forests 7(11):283. Doi: 10.3390/f7110283.

Caballero D., M. 2017. Tendencia histórica de la producción maderable en el México contemporáneo. Revista Mexicana de Ciencias Forestales 8(43):4-26. Doi: 10.29298/rmcf.v8i43.63.

Carrillo-Anzures, F., M. Acosta-Mireles, E. Flores-Ayala, J. M. Torres-Rojo, D. M. Sangerman-Jarquín, L. González-Molina y E. Buendía-Rodríguez. 2017. Caracterización de productores forestales en 12 estados de la República Mexicana. Revista Mexicana de Ciencias Agrícolas 8(7):1561-1573. Doi: 10.29312/remexca.v8i7.512.

Colegio de Profesionales Forestales de Oaxaca, A. C. (CPFO). 2015. Estudio para determinar los costos de producción y transporte de madera en rollo en el estado de Oaxaca. Ed. Comisión Estatal Forestal Oaxaca. Oaxaca de Juárez, Oax., México. 183 p.

Cranic, T. G. and G. Laporte. 1997. Planning Models for freight transportation. European Journal of Operational Research 97(3):409-438. Doi: 10.1016/S0377-2217(96)00298-6.

Di Rienzo, J. A., M. Balzarini, L. González, F. Casanoves, M. Tablada y C.W. Robledo. 2018. InfoStat Software Estadístico. Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina. Obtenido de http://www.infostat.com.ar. (12 de septiembre de 2020).

Esteves-Magalhães, W. L., G. I. Bolzon de Muniz, M. G. Lomelí R. y D. C. Batista. 2010. Estudio de la productividad de corte en madera de *Pinus ellioti* utilizando un prototipo de aserradero portátil*.* Maderas Ciencia y tecnología 12(1):43-52. Doi: 10.4067/S0718-221X2010000100005.

Estrategia Nacional de Manejo Forestal Sustentable para el Incremento de la Producción y Productividad (Enaipros). 2018. Memoria documental. Estrategia Nacional de Manejo Forestal Sustentable para el Incremento de la Producción y Productividad*.* Ed. Comisión Nacional Forestal. Ciudad de México, México. 78 p. http://www.conafor.gob.mx:8080/documentos/ver.aspx?articulo=7617&grupo=1. (25 de octubre de 2020).

George, D. and P. Mallery. 2010. SPSS for Windows Step by Step: A Simple Guide and Reference, 17.0 update. Boston: Allyn & Bacon. Boston, U. S. A. 386 p.

Gómez-Puente, A. F. 2014. Costo de transacción y cadena de producción forestal en la ladera oriental del volcán Cofre de Perote, Veracruz. Revista pueblos y fronteras digital 9(18):91-109. Doi: 10.22201/cimsur.18704115e.2014.18.25.

Jackson, S. M., T. S. Fredericksen and J. R. Malcolm. 2002. Area disturbed and residual stand damage following logging in a Bolivian tropical forest. Forest Ecology and Management 166(1-3):271-283. Doi: 10.1016/S0378-1127(01)00681-8.

Leyva, I., A. Rojas R. y Y. Segurado G. 2017. Determinación del rendimiento y calidad dimensional de la madera aserrada en aserríos en la provincia de Guantánamo. CFORES Revista Cubana de Ciencias Forestales 5(3):340-351. https://dialnet.unirioja.es/servlet/articulo?codigo=6222088. (15 de noviembre de 2020).

Martínez-González, M. A., A. Sánchez-Villegas y F. J. Faulin-Fajardo. 2006. Bioestadística amigable. Editorial Díaz de Santos. Barcelona, España: 919 p.

Marušák, R., J. Kašpar, R. Hlavatý, V. Kotek, K. Kuželka y P. Vopěnka. 2015. Alternative modelling approach to spatial harvest scheduling with respect to fragmentation of forest ecosystem. Environmental Management 133(2): 1134-1147. Doi: 10.1007/s00267-015-0558-1.

Murara-Junior, M. I., M. Pereira da Rocha y P. F. Trugilho. 2013. Estimativa do rendimento em madeira serrada de *Pinus* para duas metodologias de desdobro. Floresta e Ambiente 20(4):556-563. Doi: http://dx.doi.org/10.4322/floram.2013.037.

Nájera-Luna, J.A., Ó.A. Aguirre-Calderón, E.J. Treviño-Garza, J. Jiménez-Pérez, E. Jurado-Ybarra, J.J. Corral-Rivas y B. Vargas-Larreta. 2011a. Tiempos y rendimiento de aserrío en la región de El Salto, Durango, México. Revista Chapingo Serie Ciencias Forestales y del Ambiente 17(2):199-213. Doi: 10.5154/r.rchscfa.2010.05.034.

Nájera, J. A., Ó. A. Aguirre, E. J. Treviño, J. Jiménez, E. Jurado, J. J. Corral y B. Vargas. 2011b. Rendimiento volumétrico y calidad dimensional de la madera aserrada en aserraderos de El Salto, Durango. Revista Mexicana de Ciencias Forestales 2(4):77-91. Doi: 10.29298/rmcf.v2i4.610.

Nájera–Luna, J. A., Ó. A. Aguirre–Calderón, E. J. Treviño–Garza, J. Jiménez–Pérez y E. Jurado–Ybarra. 2011c. Tiempos y rendimientos del aprovechamiento forestal en el salto, Durango, México. Revista Chapingo Serie Ciencias Forestales y del Ambiente 17(1):49-58. Doi: 10.5154./r.rchscfa.2010.05.031.

Nájera-Luna, J. A., Ó. A. Aguirre-Calderón, E. J. Treviño-Garza, J. Jiménez-Pérez, E. Jurado-Ybarra, J. J. Corral-Rivas y B. Vargas-Larreta. 2012. Impactos de las operaciones forestales de derribo y arrastre en El Salto Durango. Revista Mexicana de Ciencias Forestales 3(10):51-64. Doi: 10.29298/rmcf.v3i10.524.

Navarro, G. A. y G. Bermúdez. 2006. Rentabilidad del manejo de bosques naturales y su competitividad respecto a otros usos de la tierra en Costa Rica. Ed. Serie de Cooperación Técnica Economía y Gobernanza Forestal. Turrialba, Costa Rica. 53 p. https://www.researchgate.net/publication/313748138_Rentabilidad_del_manejo_de_bosques_naturales_y_su_competitividad_respecto_a_otros_usos_de_la_tierra_en_Cost. (24 de otubre de 2020).

Orozco-Contreras, R., J. C. Hernández-Díaz, J. A. Nájera-Luna, P. A. Domínguez-Calleros, J. R. Goche-Telles, P. M. López-Serrano y J. J. Corral-Rivas. 2016. Rendimiento en calidad de la madera aserrada de pino. Revista Mexicana de Ciencias Forestales 7(36):37-50. Doi: 10.29298/rmcf.v7i36.58.

Ortiz-Barrios, R., S. D. Martínez, D. E. Vázquez-Rabanales y W. S. Juárez. 2016. Determinación del coeficiente y calidad de aserrío del género Pinus en la región Sierra Sur, Oaxaca, México. Colombia Forestal 19(1):79-93. https://doi.org/10.14483/udistrital.jour.colomb.for.2016.1.a06. (24 de otubre de 2020).

Pérez-Verín, G. 2006. Los recursos forestales maderables y el desarrollo social y económico en el estado de Durango. Madera y Bosques (12)1:3-15. Doi: 10.21829/myb.2006.1211246.

Rascón-Solano, J., C. M. Kiessling-Davison, V. H. Villarreal-Ramírez, L. P. Uranga-Valencia y A. Palacios-Monarrez. 2019a. Análisis Comparativo de dos Panoramas Económicos en el Desarrollo de un Proyecto de Inversión para el Ejido Forestal Cieneguita de la Barranca, Chihuahua. Revista Científica Biológico Agropecuaria Tuxpan 7(2):12-21. Doi: 10.47808/revistabioagro.v7i2.13.

Rascón-Solano, J., C. M. Kiessling-Davison, V. H. Villarreal-Ramírez, M. G. Macias-Lopez y J. J. Hermosillo-Nieto. 2019b. Fortalecimiento del capital económico del ejido forestal Agostadero de Aguirre, Chihuahua. Revista Científica Biológico Agropecuaria Tuxpan 7(2):123-133. Doi: 10.47808/revistabioagro.v7i2.56.

Rascón-Solano, J., J. M. Olivas-García, C. M. Kiessling-Davison, J. Hernández-Salas y G. López-Daumas. 2020. Incremento de la rentabilidad de la industria forestal en el Ejido Aboreachi, Chihuahua, México. Custos e @gronegócio online 15(4):219-249. http://www.custoseagronegocioonline.com.br/numero4v15/OK%2010%20costos.pdf. (18 de octubre de 2020).

Secretaría del Medio Ambiente y Recursos Naturales (Semarnat). 2011. Anuario Estadístico de la Producción Forestal 2010. Semarnat. México D.F., México. 226 p. https://www.gob.mx/cms/uploads/attachment/file/282944/2010.pdf. (11 de octubre de 2020).

Secretaría del Medio Ambiente y Recursos Naturales (Semarnat). 2020. Anuario Estadístico de la Producción Forestal 2017. Semarnat. CDMX, México. 284 p. http://dsiappsdev.semarnat.gob.mx/datos/portal/publicaciones/2020/2017.pdf. (11 de octubre de 2020).

Serrano-Ramírez, E., J. R. Valdez-Lazalde, H. M. De los Santos-Posadas, R. A. Mora-Gutíerrez y G. Ángeles-Pérez. 2019. Optimización de la producción forestal maderable

y conservación del ecosistema en bosques comunitarios en el sur de México. Bosque 40(2):195-204. Doi: 10.4067/S0717-92002019000200195.

Zavala-Zavala, D. y R. Hernández-Cortés. 2000. Análisis del rendimiento y utilidad del proceso de aserrío de trocería de pino. Madera y Bosques 6(2):41-55. Doi: 10.21829/myb.2000.621374.