

# Effect of the conversion factor \*212 on the estimation of log volume in the forest industry of Durango, Mexico

Soto-Cervantes, Jesús A.<sup>1</sup>; Mora-Silva, Blanca A.<sup>2</sup>; Montiel-Antuna, Eusebio<sup>2\*</sup>; Prieto-Ruiz, José A.<sup>2</sup>; Compeán-Guzmán, Francisco J.<sup>3</sup>; Pérez-Luna, Alberto<sup>4</sup>; García-Montiel, Emily<sup>2</sup>

<sup>1</sup> Tecnológico Nacional de México, Instituto Tecnológico de El Salto. Mesa del Tecnológico s/n. El Salto, Pueblo Nuevo, Durango, México. C. P. 34942.

<sup>2</sup> Universidad Juárez del Estado de Durango, Facultad de Ciencias Forestales y Ambientales. Río Papaloapan y Blvd. Durango s/n, Colonia Valle del Sur, Durango, Durango, México. C. P. 34120.

<sup>3</sup> Universidad Juárez del Estado de Durango, Instituto de Ciencias Sociales, Av. Veterinaria No. 501, esquina con Blvd. del Guadiana, Durango, Durango, México, C. P. 34120.

<sup>4</sup> Colegio de Postgraduados, Campus Montecillo, Texcoco, Estado de México, México. C. P. 56264.

\* Correspondence: emontiel@ujed.mx

## ABSTRACT

**Objective:** to analyze Doyle and Smalian cubing methods, comparing their behavior in the application of conversion factors in the forest industry in Durango, Mexico.

**Design/Methodology/Approach:** a total of 38 731 logs were measured in different log yards and cubed using the Doyle (board ft) and Smalian (m<sup>3</sup>) methods. The volume calculated using the Smalian method was multiplied by the operational standard \*212, a conversion factor which is used to obtain volume in tables (board feet) from roundwood. The volume estimate by diameter category and log length was analyzed using the Kruskal-Wallis test ( $p \leq 0.05$ ) to test differences between the Smalian × 212 and Doyle cubing methods.

**Results:** eighty percent of the surveyed forestry companies use the Smalian method (m<sup>3</sup>) to calculate the volume of roundwood in their log yards, then, use the factor \*212 to convert cubic meters to board feet. The volume was found to be significantly greater with the Smalian equation; however, for diameters of 65 cm and larger, the estimated volume is greater with the Doyle equation. For logs with diameters 37-55 cm, or lengths 2.44-6.71 m, estimation with the conversion factor is closer to the actual metric volume.

**Limitations/Implications of the study:** due to internal policies, 20% of the companies interviewed did not respond. However, because of the significant nature of the differences, this study confirms underestimation or overestimation of log volume when using standardized estimation methods based on economic utility. Furthermore, the accuracy of log volume estimates is relevant in terms of sustainability.

**Findings/Conclusions:** to use empirical factors is now obsolete and should not be mixed with different measurement systems, as their theoretical framework is different. Cubing methods should not be mixed, since the conversion factor \*212 currently used with Smalian equation renders estimations not equivalent to actual cubic measures under the official International Standard of Units in terms of roundwood cubing.

**Keywords:** conversion factors, Doyle method, Smalian method, log yard, International System of Units, Imperial System.

**Citation:** Soto-Cervantes, J. A., Mora-Silva, B. A., Montiel-Antuna, E., Prieto-Ruiz, J. A., Compeán-Guzmán, F. J., Pérez-Luna, A., & García-Montiel, E. (2025). Effect of the conversion factor \*212 on the estimation of log volume in the forest industry of Durango, Mexico. *Agro Productividad*. <https://doi.org/10.32854/2advnv78>

**Academic Editor:** Jorge Cadena Iñiguez

**Associate Editor:** Dra. Lucero del Mar Ruiz Posadas

**Guest Editor:** Daniel Alejandro Cadena Zamudio

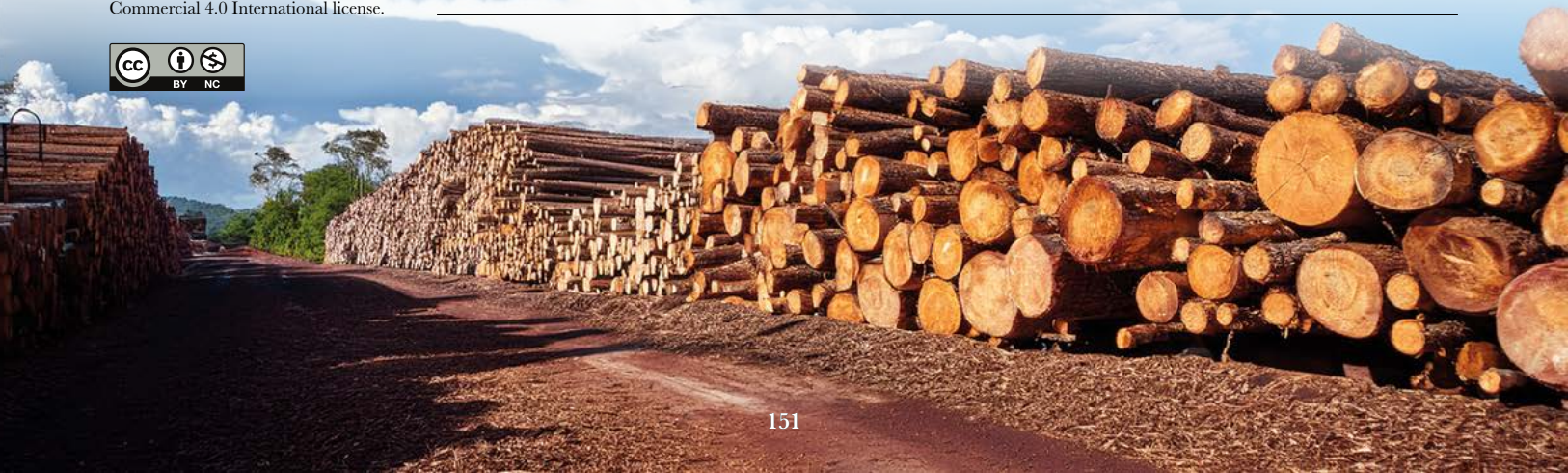
**Received:** January 10, 2025.

**Accepted:** May 19, 2025.

**Published on-line:** July XX, 2025.

*Agro Productividad*, 18(6). June. 2025. pp: 151-161.

This work is licensed under a Creative Commons Attribution-Non-Commercial 4.0 International license.



## INTRODUCTION

Mexico's forest area covers 137.8 million hectares (CONAFOR, 2019), dominated by arid ecosystems, cold temperate forests, and tropical forests. There is an annual potential for harvesting 15 to 18 million hectares of forests and tropical forests. However, in 2019, only five million hectares were under authorized commercial forest use, of which 4.4 million belong to social ownership (3.7 million to *ejidos* and 0.7 million to community property) and the rest is private property (CCMSS, 2020).

The Secretariat of Environment and Natural Resources (SEMARNAT, 2018) recorded in 2018 that the states of Durango and Chihuahua contributed 46% of the nationally authorized volume. The state of Durango leads the list of forest production with around two million cubic meters of wood per year. In addition, this state has a forest area of 10.5 million hectares, which includes forest sites with  $1.9 \text{ m}^3 \text{ ha}^{-1} \text{ year}^{-1}$  as annual current increment—ACI. (Madrid and Barrera, 2008; Soto *et al.*, 2021). These notable forest sites are managed by *ejidos*, communities, and small private owners (Suárez, 2018; Blackman and Villalobos, 2021). The main species harvested belong to the genera *Pinus* spp. (70.9% of the authorized volume) and *Quercus* spp. (9.8%); the rest (19.3%) of wood harvest belongs to other genera (CONAFOR, 2019).

The purpose of roundwood cubing is to determine the volume of harvested logs (Ordoñez *et al.*, 2012; Carvajal *et al.*, 2023; De Miguel-Díez *et al.*, 2023). According to Juárez (2014) and Hernández-Ramos *et al.* (2018), the commercial volume of a log is the quantity of solid wood with acceptable dimensions in the market. Different measurement methods are used to measure roundwood volumes. One of those is the English System which includes units that are very different to those in the Metric System. The English System is currently used in the United States; based on it, for a quick estimation of the commercial volume, it considers the smaller diameter of a log without bark in inches, and the length in feet.

The Smalian formula considers the average of the major and minor diameters (cm) of the ends of the log without bark width, as well as the length (m) to determine log volume (Vásquez and Ramírez, 2005). Whereas, the Doyle method considers the minor diameter without bark in inches and the length in feet (Romahn and Ramírez, 2010).

In Durango's forest industry, volume conversions from cubic meter to board foot are based on conversion factors such as \*212, which causes confusion in the production chain. This occurs because the differences between the two methods, when using mixed with conversion factors are not clearly documented (Hernández *et al.*, 2024a). The cubing method \*212 is traditionally used in Durango's forests. Although it is not recommended, because it is a common-use rule for estimating sawn wood production in board feet that also underestimates the volume of logs.

For all the above, with the hypothesis that the conversion factor \*212 used to convert cubic meters to board feet is not equivalent to an actual dimensional estimation based on the official metric standard; the objective of this research was to analyze Doyle and Smalian cubing methods for roundwood, and their behavior when applying the conversion factor \*212 in the forest industry of Durango.

## MATERIALS AND METHODS

### Data collection and log classification

Managers, whose logging yards are established in the city of Durango, (Durango), Mexico were randomly visited. Semi-structured interviews were conducted to learn about the cubic measurement methods and forest product conversion factors used in the marketing of roundwood. Volume estimation data were collected by direct measurement of logs in five log yards; additional data records were obtained with information on roundwood cubing.

A total of 38 731 logs were measured to estimate and compare the volume of roundwood from both cubing methods. These measurements consisted of taking the length (m), and the smallest and largest diameters (cm) without bark width at the ends of the log, using a Truper<sup>®</sup> length-meter and a tape measure, respectively. Logs were classified according to their diameter (cm) and length (m), separating them into diameter categories every five centimeters, and into length categories of one meter apiece, according to the commercial sizes used by the company (Table 1).

### Cubing of logs using the Smalian formula

The logs were cubed using the Smalian formula after classification by diameter category (Equation 1, Vásquez and Ramírez, 2005).

$$Vol = \frac{\pi}{4} \times \frac{(d_M + d_m)}{2} \times L \quad (1)$$

where:  $Vol$ =wood volume,  $m^3$ ;  $d_M$ : largest diameter of the log without bark width, m,  $d_m$ : smallest diameter of the log without bark width, m;  $L$ : length of the log, m.

Volume result was multiplied by the conversion factor \*212 to obtain the volume in board feet, then to compare volume estimates with the Doyle system. This factor is the most widely used in the Durango forest industry, according to the log yard managers interviewed.

Considering theoretical framework, this factor is based on the equivalence that the volume of a board one foot long (0.3048 m)×one foot wide (0.3048 m)×one inch thick (0.0254 m) is by definition, one board foot, which is a volumetric measure. Based on these dimensions, the metric volume of one board foot is 0.00236  $m^3$ , therefore, 1  $m^3$  is equivalent to 423.84 board feet (Vásquez and Ramírez, 2005; INAB, 2019). However, under the general assumption that the transformation coefficient from roundwood (logs) to sawnwood (boards) is 50%, it is empirically estimated that one cubic meter of roundwood is “equivalent” to 212 board feet.

In this regard, Hernández *et al.* (2024a) indicated that this factor is still used as the primary reference for estimating the equivalence between the volume of logs (roundwood) entering the sawmill and the resulting volume of timber (boards). Accordingly, it is assumed that one board foot is obtained from each Doyle foot.

**Table 1.** Logs by diameter categories and length categories, used for cubing and comparing volume estimates between methods.

Diameter class (cm)	N	DAvg± StdDev (cm)	Length class (m)	n	LAvg± StdDev (m)
1=10-15	15	14.60±0.65	1=1-2	12	1.80±0.09
2=15,1-20	4711	14.86±1.05	2=2-3	3474	2.45±0.05
3=20,1-25	13439	22.73±1.39	3=3-4	4225	3.37±0.30
4=25,1-30	9256	27.66±1.42	4=4-5	4709	4.67±0.29
5=30,1-35	6082	32.48±1.43	5=5-6	1295	5.48±0.04
6=35,1-40	3015	37.54±1.42	6=6-7	3263	6.30±0.29
7=40,1-45	1344	42.26±1.43	7=7-8	3149	7.52±0.29
8=45,1-50	553	47.44±1.42	8=8-9	1302	8.53±0.02
9=50,1-55	183	52.14±1.32	9=9-10	15360	9.69±0.18
10=55,1-60	64	57.55±1.43	10=10-11	1802	10.43±0.19
11=60,1-65	35	62.43±1.45	11=11-12	60	11.58±0.00
12=65,1-70	22	66.00±2.16	12=12-13	80	12.20±0.07
13=70,1-75	12	71.75±1.77	--	-	--

N: number of logs per diameter class, n: number of logs per length class; DAvg: average diameter; Lvg: average length; StDev: standard deviation.

### Cubing of the logs with the Doyle formula

Logs were also cubed using the Doyle formula (Equation 2), considering that the diameter to be measured is the smallest diameter of the log without bark width, in English units (Romahn and Ramírez, 2010).

$$V = (D'' - 4)^2 \times \frac{L'}{16} \quad (2)$$

Where,  $V$ : volume, board ft;  $D''$  minor diameter without bark, in;  $L'$ : length, ft.

### Statistical analysis

Data obtained using the Smalian equation multiplied by the factor 212 and Doyle equation were compared with the Kruskal-Wallis test, after proving data met the assumptions of normality (Shapiro-Wilkinson) and homogeneity of variances (Levene) tests. All statistical analyses were performed using the statistical software R<sup>®</sup> version 4.3.1 (R Core Team, 2023).

## RESULTS AND DISCUSSION

In 80% of the log yards in the forestry companies where we surveyed the owners, the Smalian method ( $m^3$ ) is used to size roundwood, using the \*212 factor to convert roundwood volume to board feet. The remaining 20% of the companies did not respond. It is important to mention that the Mexico's Federal Metrology and Standardization Law (Ley Federal sobre Metrología y Normalización, 2015) does not permit the use of English system measurements. However, this conversion is used anyway as customary, because in

extraction operations based on the purchase agreement, loggers are paid per thousands of board feet.

Significant differences ( $p \leq 0.01$ ) were found in volume estimation between the Smalian $\times$ 212 and the Doyle method. When done by diameter category, there were differences in volume in most of the categories evaluated, except category 13 (70.1-75 cm). Volume estimation by length category also showed statistically significant differences ( $p \leq 0.001$ ) in all the categories evaluated (Table 2).

Volume estimate is statistically higher with the equation Smalian $\times$ 212, except for in diameter classes 65.1-70 and 70.1-75. That is, from diameters of 65 cm onwards, although it was not significant, the volume estimate is higher with the Doyle equation (Figure 1). These results coincide with Romahn and Ramírez (2010), who argued that the Doyle method generates underestimation errors in small diameter logs and overestimation errors in large diameter logs.

Likewise, when considering all length categories evaluated, volume estimates obtained with the equation Smalian $\times$ 212 were significantly greater, compared to Doyle estimates (Figure 2).

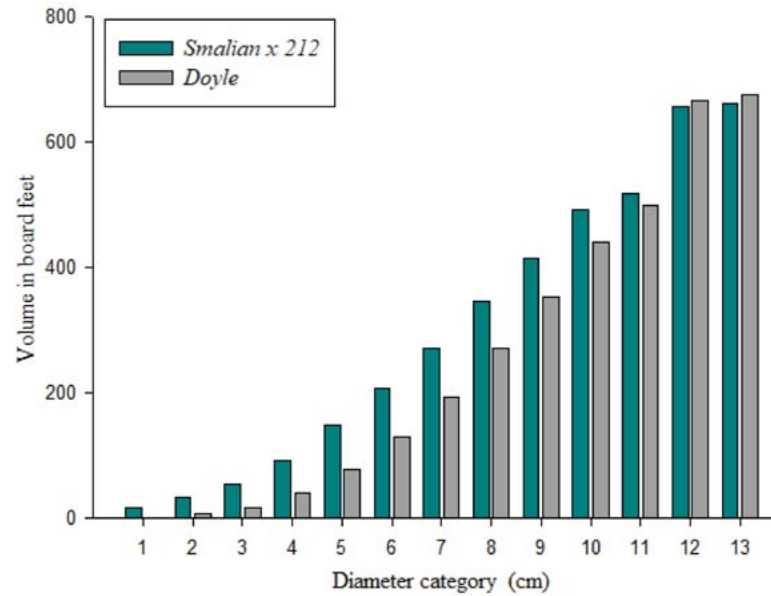
Distinct equations are used to calculate log volume. The most commonly used are those of Newton, Huber, Doyle and Smalian (Zavala and Hernández, 2000; Spelter, 2004). The Smalian and Doyle methods involve diameter measurements at the ends of the logs; whereas Newton and Huber methods are impractical equations, as those require recording the diameter in the middle of the log (Chinchilla and Gómez, 2005; Ghorani *et al.*, 2014).

Cruz and Uranga-Valencia (2013) stated that the Smalian method is less precise than the Huber method, but it is used more frequently, particularly when logs are arranged

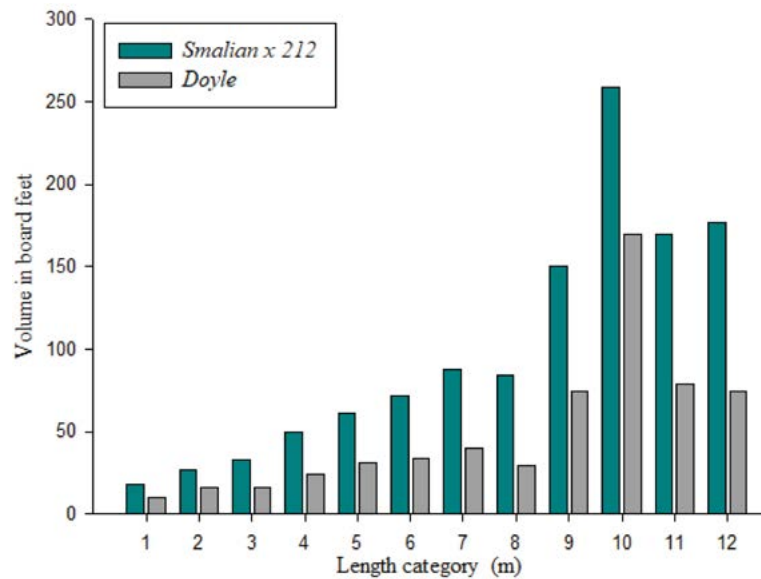
**Table 2.** Statistical comparison per diameter category and length category between the Smalian $\times$ 212 and Doyle methods, according to the Kruskal-Wallis test.

Diameter classes (cm)	p-value	Length classes (m)	p-value
1=10.0-15	0.0090	1=1-2	0.0001
2=15.1-20	0.0001	2=2-3	0.0001
3=20.1-25	0.0001	3=3-4	0.0001
4=25.1-30	0.0001	4=4-5	0.0001
5=30.1-35	0.0001	5=5-6	0.0001
6=35.1-40	0.0001	6=6-7	0.0001
7=40.1-45	0.0001	7=7-8	0.0001
8=45.1-50	0.0001	8=8-9	0.0001
9=50.1-55	0.0001	9=9-10	0.0001
10=55.1-60	0.0001	10=10-11	0.0001
11=60.1-65	0.0001	11=11-12	0.0001
12=65.1-70	0.0066	12=12-13	0.0001
13=70.1-75	0.1213 ns	--	--

p-value  $\leq 0.01$  and p-value  $\leq 0.001$  are significant; ns: non-significant.



**Figure 1.** Volume averages in board feet by diameter class (cm).



**Figure 2.** Volume averages in board feet by length class (m).

in piles where the midpoint diameter cannot be measured. In this research, many of the logs were stacked, so the Smalian method was used. When accurate log sizing is required, sections of equal or different lengths must be made and cubic measured separately, so that the cubing accuracy is greater as shorter is the length of the sections into which the trunk is divided (Alpízar, 2020).

Nájera-Luna *et al.* (2011) observed that roundwood sizing methods using the International Units System (SI), which is the updated name of the Metric System, are considered better than methods using board feet, since decimal rules give more accurate

estimates of log volumes using only diameters and lengths. Likewise, Romahn and Ramírez (2010) emphasized that the Doyle method is based on a mathematical function, but this does not mean that it is accurate, since it is based on false assumptions and as a result the generated volumes are inaccurate. Therefore, the Smalian method is one of the most widely used for commercial log sizing in Mexico (Hernández *et al.*, 2024a).

In this study, in the larger diameter categories, the volume estimates using Doyle were greater compared to those obtained with Smalian. However, the best option for forest owners in the state of Durango is the Smalian method, since the harvested trees come from native forests; those trees have diameters less than 65 cm in most cases.

Additionally, Alpízar (2020) indicated that the Doyle method has the disadvantage that the producer can only sell usable wood, since this method is based on estimating the final volume in the square dimensions that are usual in the sawmills. This means not to take into account the edges and coarse debris of the log from which other products of commercial interest are obtained; such as cape, broom handle stick, box-boards, among others (Chinchilla and Gómez, 2005).

According to Spelter (2004) and Romahn and Ramírez (2010), the use of the Doyle rule presents several drawbacks, such as mathematical oversimplicity. This formula does not consider important factors such as conicity (decrease in the diameter of the trunk from the base to the tip) and this can result in less precision in the estimation of the wood volume. Because the Doyle rule is based on an ideal cylindrical projection of the trunk, which results in precision inconsistencies. Also, this method does not take into account trunk defects such as knots, rot or curvature, which can lead to overestimation of the usable wood volume.

Log volume results from cubing when the conversion factor approximates the metric volume estimates are those with diameters ranging from 37 to 55 cm; they are also consistent with logs with lengths ranging from 2.44 to 6.71 (Table 3).

Spelter (2004) noted that the factors used to convert volumes from one cubing method to another have become obsolete. Thus, a transition into more accurate standards would improve transparency in the national log market by reducing inequalities from scales based on board feet. This would facilitate regional comparisons, as well as supporting fair play in the international market operations.

Hernández *et al.* (2024b) reported that forest managers do not supervise the spot use of the International System of Units, as opposed to the English system or any other, to measure yield in logging operations. As a result, loggers often use board feet, which are generally obtained using imprecise conversion factors. This makes it difficult to monitor the distribution and conversion of harvested volumes, which were originally projected and planned in the metric system when the forest management program and the yields in the cutting plan were formulated for each year. What means that management plan is not consistent with logging operations, in regard to commercial yields.

The use of allometric equations to estimate commercial timber volume allows for planning forest management (Revilla-Chávez *et al.*, 2021). Therefore, it is important to estimate with the greatest possible certainty the volume of logs extracted in sustainable forest management, since this estimate is equivalent to the amount of marketable volume

**Table 3.** Diameters and lengths in which the conversion factor \*212 approximates the SI metric estimated volume.

Diam 1 (cm)	Diam 2 (cm)	Average diameter (cm)	Length (m)	Vol Smalian (m <sup>3</sup> )	Vol Doyle (board ft)	Vol Smalian×212 (board ft)	Diff. (board ft)
37	37	37	2.44	0.26	55.83	55.58	0.25
37	37	37	4.27	0.46	97.70	97.27	0.43
39	38	38.5	2.44	0.28	60.07	60.18	0.11
39	38	38.5	2.44	0.28	60.07	60.18	0.11
39	38	38.5	3.05	0.35	75.08	75.23	0.14
39	38	38.5	2.59	0.30	63.82	63.94	0.12
39	38	38.5	6.10	0.71	150.17	150.45	0.28
39	38	38.5	5.49	0.64	135.15	135.41	0.25
44	41	42.5	2.59	0.37	78.32	77.92	0.40
46	42	44	2.59	0.39	83.48	83.52	0.04
46	42	44	4.27	0.65	137.50	137.55	0.06
46	42	44	6.71	1.02	216.06	216.16	0.09
48	43	45.5	2.59	0.42	88.81	89.31	0.50
55	47	51	2.44	0.50	105.18	105.60	0.42
55	47	51	2.59	0.53	111.76	112.20	0.45
60	50	55	2.44	0.58	123.01	122.82	0.19

Diam 1: Largest diameter; Diam 2: shortest diameter; Vol: volume; Diff: difference between volume estimates from both methods.

(Syed *et al.*, 2020). When calculating the volume of roundwood, it is important to have equivalents that allow for conversion from one system of units to another during processing, transportation, or marketing. Based on data from the National Forest Institute of Guatemala (INAB, 2019), 1 m<sup>3</sup> is equivalent to 424 board feet. Therefore, it is important that forestry companies in the state of Durango consider these equivalencies when assuming a sawing coefficient of 50% to convert from m<sup>3</sup> to board feet.

Knowledge and records of timber (standing trees) in metric units will allow monitoring the original volume and understanding how it is distributed among the various products, by-products, and waste throughout the entire sawnwood production chain (Hernández *et al.*, 2024a). Those authors suggested that logs should be cubed directly in metric units, without applying the English system or other usual conversion factors. The most convenient approach would use the Smalian or Huber formulas, as well as promoting the use of the International Standard Units (SI), thus avoiding underestimation or overestimation in customary commercial conversion.

Most of the studies on roundwood cubing agree on the use of a single method as standard, since differences between systems have strong economic repercussions. Moreover, differences probably impact on the sustainability of native forests, from which the raw material (timber) is obtained (Ek *et al.*, 2003; Romero, 2024).

This study contributed with significant evidence of different results when using the Doyle and Smalian cubing methods. Therefore, when using two different methods, it is advisable to use equivalent conversion factors that adapt to the reality of the forests. For this reason,

it is suggested not to use the Doyle rule and to emphasize the use of the International Standard of Units, which is metric, as it is established in forest regulations (Alpizar, 2020; Hernández *et al.*, 2024b). This will be in compliance with the Regulations of the Mexican General Law on Sustainable Forest Development (Reglamento de la Ley General de Desarrollo Forestal Sustentable– LGDFS, Article 32) which establishes that raw materials and wood forest products must be expressed in cubic meters (m<sup>3</sup>), the volumetric unit of the standard International System of units (SI).

## CONCLUSIONS

In the volume estimation of logs there was significant difference between the Smalian×212 and Doyle cubing methods. Volume estimates were significantly greater ( $p \leq 0.01$ ) with the Smalian equation. Only for logs with diameters 37 cm to 55 cm, and lengths 2.44 m to 6.71 m, the conversion factor used approximates the actual estimated volume. It is important to emphasize, according to national forest regulations, that two measurement systems, expressed with very different units, should not be mixed.

In the state of Durango, volumetric measurement methods still are used with a mix of units of measurement and conversion factors, thus affecting the marketing of roundwood. The use of the metric international standard should be prioritized over the Doyle rule, in accordance with Mexico's forest regulations (LGDFS, article 32). As a recommendation, stakeholders in the production chain should be aware of the volumetric differences of the methods analyzed in this study, to get an informed consensus on those possible economic repercussions of an imprecise cubing at the spot of roundwood marketing.

## ACKNOWLEDGEMENTS

To the forestry companies in the city of Durango (Durango, Mexico) that allowed us gathering data in their log yards.

## REFERENCES

- Alpizar, E. (2020). Ecuación práctica para cubicar madera. *Revista Científica Oriolus* 1(1):27-38. <http://revistas.utn.ac.cr/index.php/oriolus>
- Blackman, A., Villalobos, L. (2021). ¿Usar o perder los bosques? Extracción regulada de madera y pérdida de cobertura forestal en México, IDB Working Paper Series, No. IDB-WP-1219, Inter-American Development Bank (IDB), Washington, DC, doi: <https://doi.org/10.18235/0003095>
- Carvajal, J.G., Sono, D.D., López Narváez, A.L., Layana Bajaña, E.M., Chagna, E. (2023). Evaluación y análisis del factor de forma de Juglans Neotropica Diels en el predio de Yuyucocha, Cantón Ibarra. *Ciencia Latina Revista Científica Multidisciplinar*, 7(2), 10243-10262. doi: [https://doi.org/10.37811/cl\\_rcm.v7i2.6117](https://doi.org/10.37811/cl_rcm.v7i2.6117)
- Chinchilla, O., Gómez, M. (2005). Diferencias volumétricas en cuatro sistemas de medición de trozas de madera. *Revista de Ciencias Ambientales*, 29(1), 76-82. doi: <https://doi.org/10.15359/rca.29-1.7>
- CCMSS (Consejo Civil Mexicano para la Silvicultura Sostenible). (2020). El manejo forestal comunitario en México.
- CONAFOR (Comisión Nacional Forestal). (2019). El sector forestal mexicano en cifras 2019. Bosques para el Bienestar Social y Climático. Coordinación de Apoyo y Proyectos Especiales y Gerencia de Comunicación y Producción. Zapopan, Jalisco, México. 104 p.
- Cruz, G, Uranga-Valencia, L.P. (2013). Theoretical evaluation of Huber and Smalian methods applied to tree stem classical geometries. *Bosque*, 34(3), 311-317. <https://www.redalyc.org/pdf/1731/173129280007.pdf>

- De Miguel-Díez, F., Purfürst, T., Acuña, M., Tolosana-Esteban, E., Cremer, T. (2023). Estimation of conversion factors for wood stacks in landings and their influencing parameters: a comprehensive literature review for America and Europe. *Silva Fennica*, 57(1), 47. doi: <https://doi.org/10.14214/sf.22018>
- Ek, A.R., Martin, G.L., Gilmore, D.W. (2003). Chapter 11. Measuring and Monitoring of Forest Resources. *Introduction to Forest Ecosystem Science and Management*, 241-265.
- Ghorani, M., Jahani, A., Sardabi, H. (2014). Estimation of standing volume in *Populus deltoides* Marsh plantations by Huber and Smalian methods at Shafaroud forest, Guilan Province. *Iranian Journal of Forest and Poplar Research*, 22(1), 74-81. doi: <https://doi.org/10.22092/IJFPR.2013.9053>
- INAB (Instituto Nacional de Bosques). (2019). Guía práctica para la cubicación de productos forestales. Dirección de Industria y Comercio Forestal. Guatemala. 40 p.
- Hernández, J.C., Caballero, M., Nájera, J.A., Wehenkel, C., Cassian, J.M., Guardado, F.J. (2024a). Problemas principales en cada eslabón de la cadena productiva de la madera aserrada. In: Hernández-Díaz, J.C., Nájera-Luna, J.A. (Editores). Cadena productiva de madera aserrada en los bosques templados de México y su evolución a la cadena de valor. Comisión Nacional Forestal (CONAFOR). Zapopan, Jal., México. 129-162.
- Hernández, J.C., Nájera, J.A., Cassian, J.M., Caballero, S.M., Wehenkel, C., Guardado, F.J. (2024b). Integración e interacción deseable entre los eslabones de la cadena productiva de la madera aserrada. In: Hernández-Díaz, J.C., Nájera-Luna, J.A. (eds.) Cadena productiva de madera aserrada en los bosques templados de México y su evolución a la cadena de valor. Comisión Nacional Forestal (CONAFOR). Zapopan, Jal., México. 91-128. [https://www.gob.mx/cms/uploads/attachment/file/920043/Cadena\\_Productiva\\_de\\_Madera\\_Aserrada\\_compressed.pdf](https://www.gob.mx/cms/uploads/attachment/file/920043/Cadena_Productiva_de_Madera_Aserrada_compressed.pdf)
- Hernández-Ramos, J., Hernández-Ramos, A., García-Cuevas, X., Tamarit-Urias, J.C., Martínez-Ángel, L., García-Magaña, J. (2018). Ecuaciones de volumen total y de razón para estimar el volumen comercial de *Swietenia macrophylla* King. *Colombia forestal*, 27(1), 34-46. doi: <https://doi.org/10.14483/2256201x.11965>
- Juárez, Y. (2014). Dasometría. Apuntes de Clase y Guía de Actividades Prácticas. *Diseño y dibujos*. Cochabamba, Bolivia. 103 p.
- Ley Federal sobre Metrología y Normalización. (2015). Cámara de diputados del H. Congreso de la Unión, Secretaría General de Servicios Parlamentarios. Última Reforma DOF 18-12-2015. [https://www.gob.mx/cms/uploads/attachment/file/131799/38\\_ley\\_federal\\_sobre\\_metrolog\\_a\\_y\\_normalizaci\\_n.pdf](https://www.gob.mx/cms/uploads/attachment/file/131799/38_ley_federal_sobre_metrolog_a_y_normalizaci_n.pdf)
- Madrid, L., Barrera, J. (2008). Aprovechamiento forestal en Durango. <https://www.ccms.org.mx/wp-content/uploads/El-aprovechamiento-forestal-en-Durango.pdf>
- Nájera-Luna, J.A., Aguirre-Calderón, O.A., Treviño-Garza, E.J., Jiménez-Pérez, J., Jurado-Ybarra, E., Corral-Rivas, J.J., Vargas-Larreta, B. (2011). Lumber yield and production time in the El Salto region of Durango, México. *Revista Chapingo Serie Ciencias Forestales y del Ambiente*, 17(2), 199-213. doi: 10.5154/rchscfa.2010.05.034
- Ordoñez, Y., Andrade, H., Quirós, D., Venegas, G. (2012). Dasometría y cubicación de la madera. In: Detlefsen G., E. Somarriba (eds). Producción de madera en sistemas agroforestales de Centroamérica. CATIE. Turrialba, Costa Rica. 27-67.
- R Core Team. (2023). R: A language and environmental for statistical computing version 4.3.1. The R foundation for statistical computing. Vienna, Austria. <https://www.R-project.org/>
- Reglamento de la Ley General de Desarrollo Forestal Sustentable (Artículo 32) (2020). Cámara de diputados del H. Congreso de la Unión, Secretaría General de Servicios Parlamentarios. Nuevo Reglamento DOF 09-12-2020. [https://www.diputados.gob.mx/LeyesBiblio/regley/Reg\\_LGDFS\\_091220.pdf](https://www.diputados.gob.mx/LeyesBiblio/regley/Reg_LGDFS_091220.pdf)
- Revilla-Chávez, J.M., Abanto-Rodríguez, C., Guerra-Arévalo, W.F., García-Soria, D., Guerra-Arévalo, H., Domínguez-Torrejón, G., Gabriel da Silva, I.L. (2021). Allometric models to estimate the volume of *Guazuma crinita* in forest plantations. *Scientia Agropecuaria*, 12(1), 25-31. doi: <https://doi.org/10.17268/sci.agropecu.2021.003>
- Romahn, C.F., Ramírez, H. (2010). Dendrometría. Universidad Autónoma Chapingo. Texcoco, Estado de México, México. 294 p. <http://dicifo.chapingo.mx/pdf/publicaciones/dendrometría.pdf>
- Romero, E. (2024). VOLUMES: The Politics of Calculation in Contemporary Peruvian Amazonia. *Cultural Anthropology*, 39(1), 64-90. doi: <https://doi.org/10.14506/ca39.1.04>
- SEMARNAT (Secretaría de Medio Ambiente y Recursos Naturales). (2018). Anuario estadístico de la producción forestal. SEMARNAT. Ciudad de México, México. 298 p. <https://dsiappsdev.semarnat.gob.mx/datos/portal/publicaciones/2021/2018.pdf>
- Spelter, H. (2004). Converting among log scaling methods: Scribner, International, and Doyle versus cubic. *Journal of forestry*, 102(4), 33-39. doi: <https://doi.org/10.1093/jof/102.4.33>
- Soto, J.A., Padilla Martínez, J.R., Domínguez Calleros, P.A., Carrillo Parra, A., Rodríguez Laguna, R., Pompa García, M., García Montiel, E., Corral, J.J. (2021). Efecto de cuatro tratamientos silvícolas en la

- producción maderable en un Bosque de Durango. *Revista Mexicana de Ciencias Forestales*, 12(67), 56-80. doi: <https://doi.org/10.29298/rmcf.v12i67.991>
- Suárez, G. (2018). Desarrollo forestal comunitario en Durango, el camino a seguir. Consejo Civil Mexicano para la Silvicultura Sostenible. <https://ccmss.org.mx/desarrollo-forestal-comunitario-durango-camino-seguir/>
- Syed, S.S., Mohd, S.H., Zamah, N.H., Kasmin, F. (2020). A Comparative study of log volume estimation by using statistical method. *Journal of Science, Mathematics and Technology*, 7(1), 22-28. doi: <https://doi.org/10.37134/ejsmt.vol7.1.3.2020>
- Vásquez, A.M., Ramírez, A.M. (2005). Guía de Cubicación de Madera. Maderas comerciales en el área metropolitana del Valle de Aburrá, Colombia, Gobernanza Forestal, CARDER, Unión Europea. Valle de Aburrá, Medellín, Colombia. 44 p.
- Zavala, D., Hernández, R. (2000). Análisis del rendimiento y utilidad del proceso de aserrío de trocería de pino. *Madera y Bosques*, 6(2), 41-55. <https://www.redalyc.org/pdf/617/61760204.pdf>

