

cesar.cabrera@unesum.edu.ec

Correspondence:

Dasometric evaluation of *Tectona grandis* L. f. plantations in the cantons of Balzar, Guayas and Pichincha, Manabí

Evaluación dasométrica de plantaciones de *Tectona grandis* L. f., en los cantones Balzar, Guayas y Pichincha, Manabí

Cesar Alberto Cabrera-Verdesoto

Master's Degree, Forestry Engineering
Career, Universidad Estatal del Sur de
Manabí, Jipijapa-Ecuador
cesar.cabrera@unesum.edu.ec
<https://orcid.org/0000-0001-5101-3520>

Rosa Lisbeth Cely-Bravo

Master, Independent Forestry Consultant,
Chone, Ecuador, rosacely@gmail.com,
<https://orcid.org/0000-0003-0895-4506>

Marco Pedro Ramos-Rodriguez

Master's Degree, Forestry Engineering
Career, Universidad Estatal del Sur de
Manabí, Jipijapa-Ecuador
marcoramos@unesum.edu.ec
<https://orcid.org/0000-0003-0992-8414>

Jesús de los Santos Pinargote-Chóez

Master's Degree, Forestry Engineering
Career, Universidad Estatal del Sur de
Manabí, Jipijapa-Ecuador
Santos.pinargote@unesum.edu.ec
<https://orcid.org/0000-0003-1136-3125>

Yovanny Ramón Buste-Ponce

Master, Operations Manager "Grupo
Siembra". Operadora Forestal "Los
Causes", Balzar-Ecuador,
ybuste@hotmail.com
<https://orcid.org/0000-0002-6698-1492>

Abstract

The research was carried out to evaluate the dasometric development of *Tectona grandis* L. f. plantations in San Agustín farm, Balzar - Guayas, and Río Grande farm, Pichincha - Manabí, the objective was to

evaluate dasometrically *Tectona grandis* plantations in Balzar, Guayas and Pichincha, Manabí. The object of study was established as *Tectona grandis* plantations, in the field study the descriptive method was applied, which allowed obtaining data related to the growth of diameter, height and volume, with a sampling intensity of 0.89% in the San Agustín farm and 0.75% in the Río Grande farm, the plots in which the evaluations of the trees were carried out were square of 576 m², which allowed determining the average annual increment of the trees, which allowed determining the average annual increase in diameter, height and volume in the period (2018 - 2019), which presented variations in the development of individuals, this was caused by inadequate silvicultural management, the soil is optimal for the growth of *Tectona grandis* in both farms because they are fertile soils.

Keyword: growth, increment, plantations, forestry, soil.

Resumen

La investigación se realizó para evaluar el desarrollo dasométrico de las plantaciones de *Tectona grandis* L. f. de la hacienda San Agustín, Balzar - Guayas, y hacienda Río Grande, Pichincha - Manabí, el objetivo fue evaluar dasométricamente plantaciones de *Tectona grandis* en los cantones Balzar, Guayas y Pichincha, Manabí. Se estableció el objeto de estudio las plantaciones de *Tectona grandis*, en el estudio de campo se aplicó el método descriptivo, que permitió obtener datos relacionados en el crecimiento del diámetro, altura y volumen, con una intensidad de muestreo de 0,89% en la hacienda San Agustín y 0,75% en la hacienda Río Grande, las parcelas en las que se realizaron las evaluaciones de los árboles eran cuadradas de 576 m², lo cual permitió determinar el incremento medio anual del diámetro, altura y volumen en el periodo (2018 - 2019), las cuales presentaron variaciones en el desarrollo de los individuos, esto se produjo por un inadecuado manejo silvicultural, el suelo es óptimo para el crecimiento de la *Tectona grandis* en ambas haciendas por ser suelos fértiles.

Palabras clave: Crecimiento, incremento, plantaciones, silvicultura, suelo.

Introduction

Tectona grandis is one of the world's premier hardwoods, noted for its light color, excellent fiber and durability. This species is native to India, Myanmar, the Lao People's Democratic Republic and Thailand, has acclimatized in Java (Indonesia), where it was probably introduced 400 to 600 years ago, and is also established throughout tropical Asia, tropical Africa, Latin America and the Caribbean. (Rivera, 2011).

The forestry sector (plantations, native forests) the few existing plantations reflect its importance, a report of the MAE 2010, indicates that 80% of the raw material used is from forest plantations, mainly teak, balsa and laurel on the coast pine, eucalyptus, in the mountains. Therefore, it is not explained how it insists on maintaining a policy of sustainable management of forests for harvesting, thus forest engineers, it is time to echo that engineering comes from "ingenius" to demonstrate creativity, values and commitment to the sustainability of the forest, (Lopez y Muñoz, 2017). Current production of *Tectona grandis* timber does not meet the world's ever-increasing demand. The current supply is far below the market need compared to other hardwood species such as Eucalyptus and Acacia. (Barrantes, Chaves,& Vinueza, 2018). Limiting factors that may explain the low supply in tropical countries include: adaptability to edaphic factors, availability of land suitable for plantations, and low knowledge of the crop's nutritional needs and dynamics. (Acevedo, 2015).

Ecuador is a country with a diversity of regions suitable for the development of forestry plantations, with a wide range of natural resources, very fertile soils, appropriate agro-ecological conditions, competitive and climatic advantages, and one of the productive sectors with the greatest potential for development and growth. (Espinoza, 2014).

Over time, it has been observed that the species adapts very well to Ecuadorian soils and climate with promising growth results; to date, it is estimated that there are more than 30,000 hectares of teak in Ecuador in the provinces of Guayas, Los Ríos, Manabí Esmeralda and the Amazon region. (De Camino & Morales, 2013).

The cultivation of *Tectona grandis* can be established on a wide variety of soils and geological formations, but the best growth occurs in deep, porous, fertile, well-drained alluvial soils with neutral or acidic pH. In the province of Manabí, for example, the sectors of Carmen, Flavio Alfaro and Pichincha are the sectors that offer the most favorable conditions, as well as in the province of Guayas. (Kleinn & Morales, 2010).

The establishment of *Tectona grandis* plantations in different locations has allowed different results in terms of growth and development of the species; these experiences in combination with the silvicultural management of each plantation, defines the production and, therefore, the competitiveness of the plantations, possibly improving the quality of wood and even reducing the time for its use. During the research, after evaluating both plantations, it was observed that apparently the *Tectona grandis* crop adapts very well and does not present disease problems; however, there were flaws in the management of the crop, since few people are familiar with adequate silvicultural management. Taking into account that not all areas offer optimal conditions for establishing plantations of *Tectona grandis* (Instituto Nacional de Bosques, 2015).

Materials and methods

The research was carried out at the San Agustín farm in the Balzar canton, Guayas province, and at the Río Grande farm in the Pichincha canton, Manabí province:

The study areas are 109 ha San Agustín farm and 129 ha Río Grande farm where there are fifteen (15) permanent rectangular plots in each farm, 24m wide by 25m long, 576m², the same that are systematically, the age of the last measurement to carry out the research is 4 years.

Figure 1. Study area of the San Agustín farm in Balzar canton, Guayas province.

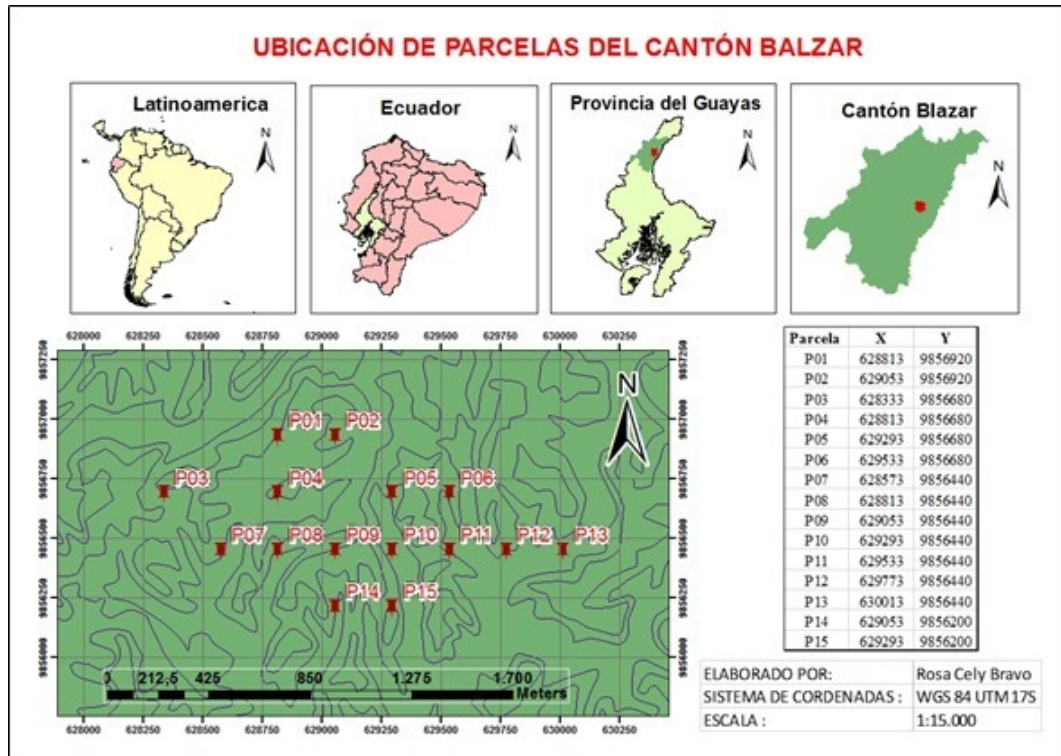
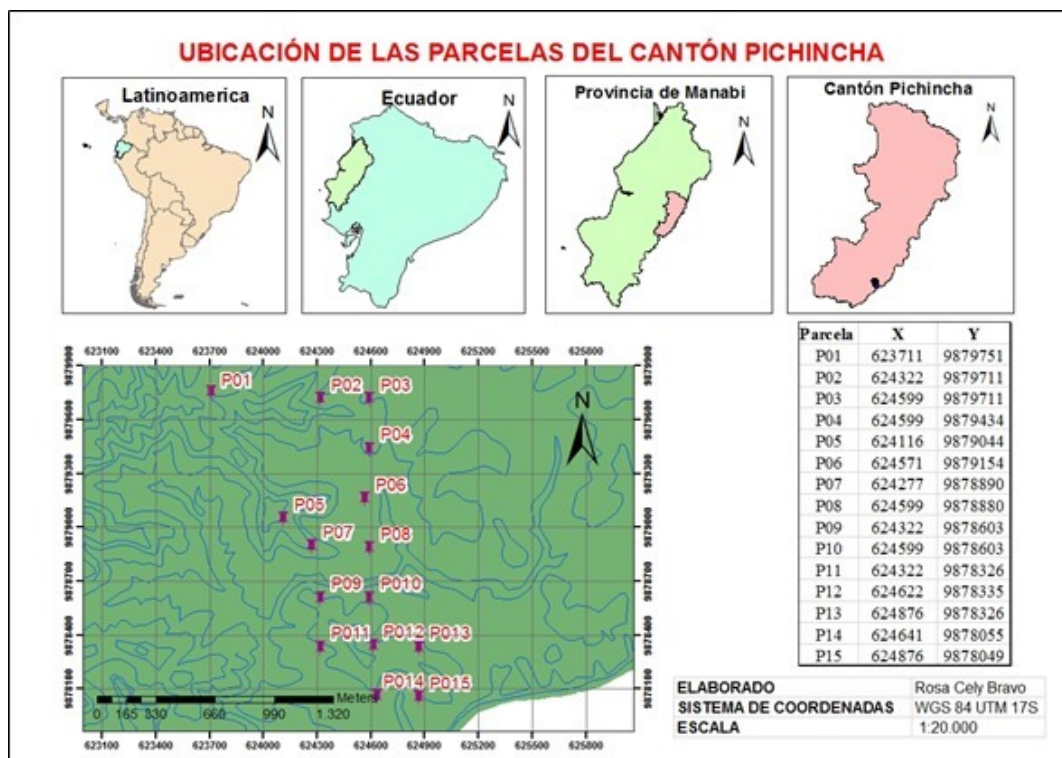


Figure 2. Study area of the Rio Grande farm in the canton of Pichincha, province of Manabí.



Sample selection

Sampling units were identified in the plots of both farms with the same dimension, shape and sampling intensity of 0.89% in the San Agustín farm and 0.75% in the Río Grande farm, the plots in which the evaluations of the planted trees were carried out are rectangular. The data were collected in field sheets and then tabulated in an Office Excel spreadsheet applying the formula to calculate volume and to calculate the growth of the Average Annual Increase and Annual Periodic Increase, the division of the number of years of the plantation by the dasometric variables (diameter, height and volume) was used and then processed in the statistical software INFOSTAT.

Within this research project to obtain the sampling intensity calculation the following formula was applied: (Pionce, Suatunce, Pionce & Ortega, 2018).

$$UM = \frac{n \times 100}{N}$$

Where:

UM= Sampling Unit

N= Population size

n= Sample size

Distribution of sampling plots

For the distribution of the plots, a grid was used at the scale of the farm sketch, the number of points was located, each one representing a plot in reference to the sampling intensity. Each plot is distributed at 250 m in a systematic way.

Shape and size of plots

In commercial forestry plantations, it has been found that there is an optimum reaction between sampling efficiency and consumptions when the plot includes between 15 and 20 trees. (Merino, 2010). Considering this principle, the plot size used is shown.

Table 1. Processing data for the plots at the Balzar and Pichincha sites.

Square plot	
Plot size	24 m x 24 m
Trees/ha	833
Trees/plots	48
Plot area (m ²)	576 m ²

Accuracy, reliability and sampling intensity

It is advisable to use a sampling intensity from 0.005% when there are areas of 50 ha or more. However, in small plantations (1 to 6 ha) the size of the sampling error is very high and a larger number of plots is required to obtain adequately representative estimates. (Otzen & Manterola, 2017).

For this research, the sampling intensity applied was 0.89% San Agustín and 0.75% Río Grande, respectively, with 15 plots distributed in each of the farms at 250 m between plots.

The distance between plots was obtained based on the following formula:

$$D = \sqrt{\frac{A}{P}}$$

Where:

D= The distance between plots

A= The area of the plantation in square meters (m²)

P= Number of plots to be sampled according to sampling intensity

The *Tectona grandis* plantations were established in 2015, with a spread of 3 m between plants and 4 m between rows, from which the 576 m plots were sized², this methodology considers quantitative aspects by measuring the dasometric variables: diameter, height and volume.

The plantation is established at (3 m x 4 m) (833 trees/ha).

Variable to evaluate

Diameter

For the evaluation of diameter (cm), the first step was to identify the plots located in the San Agustín and Río Grande farms. Once the plots were identified, the selected trees were evaluated from the base of the tree up to 1.30 m in height with the help of a diametric tape.

Height

The Haglof Vertex IV hypsometer was used for this variable. This instrument provides reliable height measurements and is used by Grupo Siembra's technicians when conducting forest inventories.

Volume

For this evaluation the form factor of 0.6 (established by Grupo Siembra) was used, once the data was obtained the volume (m³) was determined using the following formula: (Indio, 2017).

$$V = AB * H * Fc \quad (1)$$

Where:

V= Volume

AB= Basal area

H= Height

Fc= Form factor

Average annual increase (AAR)

In the determination of this variable, the behavior of the individuals from one year to the next in the development of diameter, height and volume was evaluated using the following equation: (Imaña & Encinas, 2008).

$$IMA = Y_t/t_o \quad (2)$$

Where:

AAR= Average annual increase

t_o = Age from time zero

Y = dimension of the variable under consideration

In the case of volume:

$$IMA = \frac{\text{volumen_del_arbol}}{\text{edad}}$$

Annual percentage increase (PPI)

The annual periodic increment was determined for the period (2016 - 2019) using the following equation (Imaña & Encinas, 2008).

$$IPA = (Y_{(t+n)} - Y_t)/n \quad (3)$$

Where:

PPI= annual periodic increase

Y= dimension of the variable under consideration

t= age

n= period of time

In the case of volume:

$$IPA = \frac{\text{volumen_em2019} - \text{volumen_em2016}}{4_años}$$

Soil analysis

For the collection of the soil samples, two calicatas (0.50 cm x 0.50 cm) wide and 1 m deep were made, with the help of a hole-opening shovel and a hand shovel the samples were collected and then placed in polyethylene bags with zip closure, once the samples were obtained, each one was labeled with its respective codification. The samples were taken to the soil analysis laboratory of the Estación Experimental Tropical Pichilingue (INIAP), to perform the respective analysis and determine the physical and chemical characteristics of the soil of both plantations.

Result

Growth of *Tectona grandis* plantations at the San Agustín and Río Grande farms in 2019.

Basal area growth

Basal area growth in 2019 in *Tectona grandis* plantations on the San Agustín farm was 8.61 m² and 11.46 m² on the Río Grande farm, with a difference of 2.85 m² in basal development between plantations.

Diameter growth

In 2019, the diameter growth in the *Tectona grandis* plantations at the San Agustín farm was 15.36 cm and 15.58 cm at the Río Grande farm, obtaining a similar development between the plantations.

Height growth

The results obtained in the evaluations corresponding to the height for 2019 at the San Agustín farm were 13.70 m and 14.38 m at the Río Grande farm, where a difference of 0.68 m in height can be observed between the plantations.

Volume growth

The results obtained in the evaluations corresponding to volume growth in 2019 at the San Agustín farm were 70.74 m³ and 98.85 m³ at the Río Grande farm; a difference of 28.11 m³ in volume between the plantations can be observed.

Average annual increase for the San Agustín and Río Grande farms

The results were obtained by applying equation (2) where the average annual increase in diameter, height and volume in 2018 - 2019 was evaluated.

Average annual increase in diameter

The results of the average annual increase in diameter in 2018 - 2019, showed a decrease of 0.14 cm in the San Agustín farm, and an increase of 0.01 cm in the Rio Grande farm, the decrease in the San Agustín farm was due to the burns on the property and the poor application of phytosanitary thinning.

Average annual height increase

The results of the average annual increase in height in the year 2018 - 2019, there was a decrease of 0.12 m in the San Agustín farm, and an increase of 0.46 m in the Rio Grande farm, as can be seen the Rio Grande farm obtained a greater average annual increase in height.

Average annual volume increase

The results of the average annual increase in volume in 2018 - 2019, presented an increase of 1.58 m³ in the San Agustín farm, and an increase of 8.96 m³ in the Rio Grande farm, as can be seen the Rio Grande farm obtained a higher average annual increase in volume.

Periodic annual increase of the San Agustín and Rio Grande estates

The results were obtained by applying equation (3) where the annual periodic increase in diameter, height and volume in the period (2016 - 2019) was evaluated.

Periodic increase in diameter

The results of the periodic increase in diameter in the period 2016 - 2019, showed a decrease of 1.15 cm in the San Agustín farm, the Rio Grande farm showed a decrease of 2.68 cm, the reasons for these decreases were due to the burns that occurred on the property and the poor application of phytosanitary thinning.

Periodic increase in height

The results of the periodic increase in diameter in the period 2016 - 2019, presented an increase of 1.43 m in the San Agustín farm, the Rio Grande farm presented an increase of 1.02 m, the results obtained show that the San Agustín farm presented greater development in height.

Periodic volume increase

The results of the periodic increase in volume in the period 2016 - 2019, presented an increase of 0.33 m³ in the San Agustín farm, the Rio Grande farm obtained an increase of 35.1 m³, in the results obtained show that the Rio Grande farm obtained a superior development in relation to the San Agustín farm.

Soil analysis

With the soil samples collected at the San Agustín and Rio Grande farms, high, medium and low percentages of soil chemicals were obtained, the results of which are detailed below:

Table 2: Soil analysis of the San Agustín plantation, Balzar canton, Guayas province.

Lot 1	pH	Ppm		Mg/100ml			Ppm			Texture
		N	P	Ca	Mg	K	Faith	Cu	Mn	
5,2	13B	14M	12A	2,5A	0,72A	273A	7,5M	16,6M	5,6M	Clayey

Legend: (A): high, (M): medium, (B): low.

Table 3: Soil analysis of the Rio Grande plantation, Pichincha canton, Manabi province.

Lot 2	pH	Ppm		Mg/100ml			Ppm			Texture
		N	P	Ca	Mg	K	Faith	Cu	Mn	
5,3	17B	14M	15A	3,6A	0,58A	247A	11,6M	17,6M	4,7M	Clay loam

Legend: (A): high, (M): medium, (B): low.

The result of the soil analysis of the San Agustín farm shows a clay texture, with a pH of 5.2, the nutrients that presented a high level were: Calcium (Ca), Magnesium (Mg), Potassium (K), Iron (Fe), the nutrients with a low level were: Nitrogen (N). The Río Grande farm has a clay loam texture, with a pH of 5.3, the nutrients with a high level were: Phosphorus (P), Copper (Cu), Manganese (Mn), Zinc (Zn), the nutrient with a low level was: Nitrogen (N). The macronutrients Calcium (Ca), Magnesium (Mg) and Potassium (K), the higher the quantity, the higher the degree of soil fertility and the development of the species *T. grandis*, in the San Agustín and Río Grande farms, being these fertile soils with a neutral toxicity level according to the data obtained in relation to Iron (Fe) and Manganese (Mn).

In the 2019 dasometric evaluation of *Tectona grandis* plantations, with 6 years, the diameter growth was 15.36 cm in the San Agustín farm and 15.58 cm in the Río Grande farm. Telles (2016) obtained results in *Tectona grandis* stands of 7 and 11 years established with average diameters of 14.72 cm and 16.01 cm, similar to the results obtained in the San Agustín and Río Grande plantations.

Height growth was 13.70 m at Hacienda San Agustín and 14.38 m at Hacienda Río Grande. Lopez, Montilla, Solano, Belezaca & Nuñez (2019) obtained heights of 9.61 m at 6 years and 10.61 m at 7 years, which differs from the results obtained at the San Agustín and Río Grande farms. Camacho, Ramírez, De los Santos & Zamudio (2013) obtained results at heights of 10 m and 15 m, which differed from the results obtained at the San Agustín and Río Grande farms.

Volume growth on the San Agustín farm was 70.74 m³/ha and 98.85 m³/ha on the Río Grande farm. Ladrach & Zobel (2009) obtained a volumetric growth of 153.10 m³/ha and Suatunce, Díaz & García obtained a volumetric growth of 153.10 m³/ha. (2010) obtained a volumetric growth of 195.67 m³/ha in 7 and 10 year old stands at a density of 6 x 6, this differs with the results obtained between the San Agustín and Río Grande farms. Casal, Vásquez, Cetina & Campos (2016) evaluated forest plantations in three communities of the Mixteca Alta Oaxaqueña and determined that the volume of *Tectona grandis* individuals was 11 m³, lower than the results obtained from the San Agustín and Río Grande

plantations. Armijos (2013) carried out volumetric tables in three plantations of *Tectona grandis* and determined that the plantations obtained a real volume of 201.90 m³/ha, higher than the results obtained from the San Agustín and Río Grande plantations.

The average annual diameter increase for the San Agustín and Río Grande farms in the period 2018 - 2019 was 0.14 cm/year and 0.01 cm/year. Ramirez (2017) determined the mean annual increment in 60 permanent plots of *Tectona grandis* with ranges from 1 to 6 years, concluded that the mean annual increment of diameter ranges from 2.7 cm/year to 3.7 cm/year, higher than the result obtained in the San Agustín and Río Grande farms. The average annual increase in height on the San Agustín and Río Grande farms was 0.12 m/year and 0.43 m/year. Ramirez (2017) determined the mean annual height increment in 60 permanent plots of *Tectona grandis* ranged from 2.00 to 3.28 m/year, higher than those obtained in the San Agustín and Río Grande farms. The average annual increase in volume in the San Agustín and Río Grande farms was 1.58 m³/year/ha and 8.96 m³/year/ha. ³³Ramirez, (2017) determined the average annual volume increase in 60 permanent plots of *Tectona grandis* ranges from 2.7 to 9.7 m³/year/ha, with differences with the results obtained in the San Agustín and Río Grande farms. (Figueroa, 2018) The study showed the relationship of the volumetric increase of *Tectona grandis* with the genetic origin, in which it stands out with 0.62 m³/year/ha in the volumetric valuation, a lower result than that obtained in the San Agustín and Río Grande farms.

Periodic diameter increment at the San Agustín and Río Grande farms was 1.15 cm/ha and 2.68 cm/ha. Muñoz, Coria, García & Balam (2009) obtained results of 5.10 cm in diameter, higher than those obtained in the San Agustín and Río Grande farms, which were 1.43 m/ha and 1.02 m/ha. Ladrach & Zobel (2009) and Suatunce et al, (2010) carried out research at three different sites and stipulated different height developments, giving average results of 2.8 m; 1.3 m; 5.36 m, higher than the results obtained at the San Agustín and Río Grande farms. The periodic increase in volume between the San Agustín and Río Grande farms was 0.33 m³/ha/year.³ Ojeda (2011) determined the site index in three plantations of *T. grandis* of the company Rey Banano del Pacifico, where they obtained significant volume results of 57.10 m³/ha/year. This is higher than the annual periodic increase in volume of the San Agustín and Río Grande plantations.

The soil analysis carried out in the *Tectona grandis* plantations in the San Agustín and Río Grande farms, obtained a clayey and clay loam texture, respectively. Salcedo, Ruiz, Hernández, Cruz, Bernabé, Orozco, Ramírez, Anzaldo & Delgado (2018) demonstrated that *Tectona grandis* plantations develop better in clay loam textures, and that it has the particularity of adapting to a great variety of soils. Balám, Gómez, Vargas, Aldrete & Obrador (2015) established that southeastern Mexico is a region of high potential for the establishment of commercial forestry plantations due to the clay texture of the soil in the area studied. This shows that the San Agustín and Río Grande farms have similar soils to the studies carried out by the other authors. The pH of the soil in the San Agustín and Río Grande farms was 5.2 and 5.3. The study by Mollinedo, Ugalde, Alvarado, Verjans & Rudy (2005) determined the pH value of the soil in permanent plots of *Tectona grandis* where they obtained variations in pH of 4.90 and 5.95, considering them as moderately acid values, this study shows that there are differences with the pH presented by the San Agustín and Río Grande farms. Ypushima, Salcedo, Manríquez, Silva, Zamora & Hernández (2014) determined the soil pH in a plantation of *T. grandis* located in Veracruz and Nayarit, Mexico where they obtained pH values of 4.14 and 5.12 respectively, this study shows pH values lower than the results obtained in the San Agustín and Río Grande plantations.

Conclusions

It was determined that the average annual increase in diameters, height and volume in the period (2018 - 2019) in the *Tectona grandis* plantations of the San Agustín and Río Grande farms, which presented variations in the development of individuals, due to the little silvicultural management carried out in the plantations.

The estimation of the periodic increment in the period (2016 - 2019) in the *Tectona grandis* plantations of the San Agustín and Río Grande estates presented differences in diameter, height and volume, due to poor silvicultural management (burning, poorly applied thinning) that have existed in the plantations of the two estates.

The soil that exists in the forest plantations of the San Agustín and Río Grande farms determined that they are fertile soils with an optimum pH, clay and clay loam texture and nutrients such as calcium, magnesium and potassium in high levels for the development of *Tectona grandis* in both plantations, the higher the content of these nutrients the better the soil fertility.

Acknowledgments

We would like to thank the "Grupo Siembra" for their support with their forest plantations at the San Agustín and Río Grande farms, as well as all the authors for the study carried out.

References

- Acevedo, A. (2015). Soil quality indicators in the cultivation of Teak (*Tectona grandis* Linn, F) in the region of San Onofre, Sucre. National University of Colombia. 106 p.
- Armijos, D. (2013). Construction of volumetric tables and calculation of form factor (ff.) For two species, teak (*tectona grandis*) and melina (*gmelina arborea*) in three plantations of Reybanpac CA. In the province of Los Ríos. 101. http://dspace.epoch.edu.ec/bitstream/123456789/2967/1/33T0119_Armijos_Darwin.pdf
- Balám, M., Gómez, A., Vargas, J., Aldrete, A., & Obrador, J. (2015). Initial fertilization of commercial plantations of Teak (*Tectona grandis* Linn F.) in southeastern Mexico. *Revista Fitotecnia Mexicana*, 38(2), 205-212. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S018773802015000200011.
- Barrantes, G., Chaves, H., & Vinueza, M. (2018). FORESTRY A transformed vision for development and conservation.
- Camacho, A., Ramírez, H., De los Santos, H., & Zamudio, F. (2013). Yield tables for teak (*Tectona grandis* L.) in the state of Campeche. *Revista Mexicana de Ciencias Forestales*, 4(19), 92-101. <https://doi.org/10.29298/rmcf.v4i19.381>. <https://doi.org/10.29298/rmcf.v4i19.381>
- De Camino, R., & Morales, J. (2013). Teak plantations in Latin America: Myths and realities. *Tropical Agricultural Research and Higher Education Center (CATIE)* 411 p.
- Espinoza, D. (2014). Importance and economic impact in balzar in the export of teak. Degree thesis. Universidad Católica. Guayaquil. 95 p.
- Figueroa, S. (2018). Evaluation of genetic parameters of *Tectona grandis* linn. At 11 years of age, in the Pacific of Costa Rica. Technological Institute of Costa Rica. Cartago. 68 p.
- Imaña, J., & Encinas, O. (2008). *Epidometría Forestal*. University of Brasilia Department of Forest Engineering 72 p.

- Indio, Y. (2017). Allometric projections in plantations of *Tectona grandis* L.f. (Teak) in the area of Balzar, Guayas province. 54 p.
- Kleinn, C., & Morales, D. (2010). Methodological considerations when establishing permanent observation plots in natural forest or forest plantations. Central American Forestry Journal (CATIE), 6-12. https://repositorio.catie.ac.cr/bitstream/handle/11554/5953/Consideraciones_metodologicas_al_pdf.pdf?sequence=1&isAllowed=y
- Ladrach, W., & Zobel, F. (2009). Teak plantation management for solid products. International Society of Tropical Forestry, 1-27. http://www.istf-bethesda.org/specialreports/teca_teak/teca.pdf.
- López, T. R., Montilla, Y., Solano, E., Belezaca, C., & Núñez, M. (2019). Dasometric increments in plantations of *Tectona grandis* L. f. (Teak) in the province of Guayas: Revista Amazónica Ciencia y Tecnología. Volume 8 (2): 107-113. <https://www.uea.edu.ec/revistas/index.php/revistaamazonica/article/view/242/297>.
- Merino, J. (2010). Quality evaluation and assessment of a pine plantation (*Pinus radiata* D Don), in the community of Chausan San Alfonso, Palmira parish, Guamote canton, province of Chimborazo. 147 p. <http://dspace.esPOCH.edu.ec/bitstream/123456789/711/1/33T0065.pdf>
- Mollinedo, M., Ugalde, L., Alvarado, A., Verjans, J. M., & Carles Rudy, L. (2005). Soil-tree relationship and site factors in young teak (*Tectona grandis*) plantations in the western zone of the Panama Canal watershed. Agronomía Costarricense, 29(1), 67-75. <https://www.redalyc.org/pdf/436/43629107.pdf>
- Muñoz, J., Coria, V., García, J., & Balam, M. (2009). Evaluation of a plantation of three fast-growing tropical species in Nuevo Urecho, Michoacán. Forest Science in Mexico, 61-87 p. <http://www.scielo.org.mx/pdf/cfm/v34n106/v34n106a4.pdf>. <http://www.scielo.org.mx/pdf/cfm/v34n106/v34n106a4.pdf>
- Lopez A., Muñoz, P. (2017). Forestry production an activity with high potential in Ecuador requires a change of vision. Latitud Cero Forests Magazine. Vol. 7(1) 80-95 p. <https://revistas.unl.edu.ec/index.php/bosques/article/view/186/180>
- Ojeda, M. (2011). Determination of the site index in three teak (*Tectona grandis*) plantations of the company Reybanpac Reybanano del Pacifico C.A. 108 p.
- Otzen, T., & Manterola, C. (2017). Sampling Techniques on a Study Population. Int. J. Morphol., 35(1):227-232.
- NATIONAL FOREST INSTITUTE. 2015. Growth and Productivity of Teak (*Tectona grandis* L.f.) Forest Plantations in Guatemala. Technical Series No. DT-001(2015). Guatemala. 42 p.
- Pionce, G., Suatunce, J., Pionce, V., & Ortega, G. (2018). Inventory of non-timber forest products (NTFPs) from a semi-humid forest in southern Manabí, Ecuador. Journal of the Selva Andina Research Society, 9(2), 80-95. <https://doi.org/10.36610/j.jsars.2018.090200080>. <https://doi.org/10.36610/j.jsars.2018.090200080>.
- Ramirez, L. M. (2017). Mean annual increment of teak (*Tectona grandis* L.f.) in commercial plantations, Puerto Inca district, Huánuco-Peru. 97 p. http://190.116.36.86/bitstream/handle/UNC/1718/T016_47261481_T.pdf?sequence=1&isAllowed=y
- Rivera M. (2015). Characterization of the silvicultural situation of teak (*Tectona grandis* Linn. F.) in plantations and agroforestry systems in the Nicoya Peninsula, Costa Rica. 18-50.
- Salcedo, E., Ruiz, A., Hernández, E., Cruz, R., Bernabé, A., Orozco, E., Ramírez, C., Anzaldo, J., & Delgado, E. (2018). Soil properties and nitrogen as indicators of growth in commercial teak plantations. Revista Mexicana de Ciencias Forestales Vol. 10(52). <http://www.scielo.org.mx/pdf/remcf/v10n52/2007-1132-remcf-10-52-33.pdf>.

- <http://www.scielo.org.mx/pdf/remcf/v10n52/2007-1132-remcf-10-52-33.pdf>
- Suatunce, P., Díaz, T., & García, L. (2010). Effect of Planting Density on the Growth of Four Tropical Forest Species. *Science and Technology*, 3(1), 23-26. <https://doi.org/10.18779/cyt.v3i1.42>
- Telles, A. (2016). Growth and physico-mechanical properties of *Tectona grandis* LF (Teak) from a commercial plantation in Michoacán Mexico. 83 p.
- Vásquez-García, I; Cetina-Alcalá, V.M; Campos-Bolaños, R; Casal-Ángeles, L.F. (2016). Evaluacion de Plantaciones Forestales en Tres Comunidades de la Mixteca Alta Oaxaqueña. 9(2). 12-19. file:///C:/Users/CESAR/Downloads/valeria_sias,+Journal+manager,+con-2.pdf.
- Ypushima, A. L., Salcedo, E., Manriquez, R., Silva, J., Zamora, J., & Hernandez, E. (2014). Wood properties and relationship of nutrient status with growth in teak. *Rev. Mex. Sci. For.* Vol. 5(24). 26-39. <http://www.scielo.org.mx/pdf/remcf/v5n24/v5n24a4.pdf>