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Economic assessment of wood producing species surrounding «La Demajagua» national monument, Cuba

Valoración económica de las especies productoras de madera circundantes al monumento nacional «La Demajagua», Cuba

Yudemir Cruz Pérez[1]

Fabio Alberto Piñeiro Luis[2]

Ana Rita Bertot Sábado[3]

Jorge Carlos Castro Reyes[4]

[1]Universidad de La Habana, Cuba. E-mail: yudemir.cruz@ftur.uh.cu
[2]Universidad de Granma, Cuba. E-mail: fabiopi@nauta.cu
[3]Empresa de Seguros de Cuba. E-mail: anarb@nauta.cu
[4]Instituto de Investigaciones Agroforestales. E-mail: sanvegetal2@tercerfrente.inaf.co.cu

ABSTRACT

The purpose of the work was to economically value the wood producing species surrounding the National Monument «La Demajagua» in Granma, Cuba; for which three stages of investigation were executed: the dasometric evaluation, classification of assortments and valorization of the masses. There were found a high number of trees per hectare and a forest in latizal stage, with diametric classes that denoted lack of silvicultural treatments. *Albizia lebbeck (L.) Benth* and *Cordia gerascanthus L.* had the largest timber stocks, and *Cedrela odorata L.*, *Caesalpinia cubensis Greenm.* and *Leucaena leucocephala (Lam.) de Wit* the smallest stock; predominantly high coefficients in the preferred productions. Assortments of sawed timber were of greater perspective for the reimbursement of the investment, which could be maximized with the total felling of *A. lebbeck*, *Albizia procera (Roxb.) Benth.* and *L. leucocephala*, and thinning of *C. odorata*, *C. gerascanthus*, *Swietenia macrophylla King. x Swietenia mahagoni L. Jacq.* and *C. cubensis*.

Keywords: economic valuation; forest resource.

RESUMEN

El propósito del trabajo fue valorar económicamente las especies productoras de madera circundantes al Monumento Nacional «La Demajagua» en Granma, Cuba; para lo cual se ejecutaron tres etapas de investigación: la evaluación dasométrica, clasificación de surtidos y valorización de las masas. Como resultados se encontró un elevado número de árboles por hectárea y un bosque en estadio de latizal, con clases diamétricas que denotaron falta de tratamientos silviculturales. *Albizia*

lebbeck (L.) Benth y *Cordia gerascanthus L.* presentaron las mayores existencias maderables, y *Cedrela odorata L.*, *Caesalpinia cubensis Greenm.* y *Leucaena leucocephala (Lam.) de Wit* las menores; predominando coeficientes altos en las producciones preferentes. Los surtidos de madera aserrable fueron de mayor perspectiva al reembolso de la inversión, que podrá maximizarse con la corta total de *A. lebbeck*, *Albizia procera (Roxb.) Benth.* y *L. leucocephala*, y el raleo por lo bajo de *C. odorata*, *C. gerascanthus*, *Swietenia macrophylla King.* x *Swietenia mahagoni L. Jacq.* y *C. cubensis*.

Palabras clave: valoración económica; recurso forestal.

INTRODUCTION

When responsibly managed, forests can contribute to the provision of environmental services (soil and water protection, rehabilitation of degraded lands, landscape restoration, habitat development and carbon sequestration), as well as social services and support to people's livelihoods (regional development, income generation, employment and recreation). They can also counteract the pressure on primary forests and other valuable forest ecosystems. Cruz, (2010)

Forests, both productive and protective, should be fully recognized for the commercial and non-commercial benefits they provide, in the first instance considering primary forest goods, timber and non-timber, as well as social, cultural and environmental services. Maes et al., (2016)

Achieving an appropriate balance between the rates of return on forest investment and the costs and benefits of forests in terms of sustainable livelihoods, land use and forest management, as well as improving economic and market valuation to recognize the full range of goods (wood, fibre, bioenergy...) and environmental services (carbon sequestration, biodiversity conservation, soil and water protection, ecotourism, recreation and aesthetics) derived from them, is an essential element in achieving sustainable forest management. Edens and Hein, (2013)

The development of decision-support tools such as forest valuation allows the supply of goods and services from forests, both spatially and temporally, to be sustained by decreasing the pressure on other stands with different destinies and especially for conservation and protection. Cruz and Bejerano, (2017).

Therefore, producing methods that better reflect the total value of forests in order to justify investments made in forest activity will better express the application of the full value of the goods and services generated by forests in the planning, management and monitoring carried out by companies and will make all operational plans for forest use more flexible and also establish priorities in terms of land use. Falcão and Borges, (2002)

In Cuba, forest management is carried out by productive forestry entities, which is planned and developed through a forest management project that covers the entire forest heritage Herrero, (2004); however, these long-term planning documents still lack the application of forest valuation tools capable of perfecting all the work with forest investments and the forestry accumulations that will result from them. Cruz, (2010)

According to Archivo Historico de Manzanillo of 2018, the surroundings of the current "La Demajagua", were covered by forests, where the species of malvaceous referred, however from the nineteenth century to date many

changes have been, so much so that until the late twentieth century the site was surrounded by reeds, that later in 2001 with the Alvaro Reynoso Task, the forest plantations that exist today were created, but without technical criteria that would favor the economic objective of producing round wood, for which they were established as regular mass and producing forests.

Since 2007, this forest mass has been part of the patrimony of the Silvicultural Based Enterprise Unit of Manzanillo of the Agro-Forestry Company "Granma", decision makers who have only been able to carry out wood exploitation actions without previous planning, accentuating the general unfavourable situation, whose initial investment still does not show a positive return rate, and furthermore, its function does not correspond to the environment in which it is located. Therefore, the objective of the research was: to economically value the wood-producing species surrounding "La Demajagua" National Monument.

MATERIALS AND METHODS

Physical and geographical description of the study area

The research was carried out between November 2016 and June 2017, in the area of Lot 16 of the Silvicultural Based Enterprise Unit of Manzanillo, in the homonymous municipality of Granma province, surrounding the historical site "La Demajagua" National Monument. Geographically, it is located to the northwest of the municipality, bordering the El Ranchón country road to the north, the land of the usufructuary Juan Naya and the El Ranchón farmhouse to the east, La Demajagua and the road to Troy to the west, and La Demajagua road to the south. The lot covers a total area of 164.4 hectares.

The relief is part of the interior coastal plain of the Gulf and has no elevations, is very flat and has gentle slopes ranging from zero to three percent, which affects surface drainage where the slope is less than one percent, with exposure to the north-northeast.

The soil is a reddish-brown fersialite, a leached subtype, moderately deep, with the presence of clay minerals and a stable coarse aggregate structure, with a pH that behaves between neutral and slightly acidic (values between 7 and 5,5) and average values of organic matter (2,3 %). The hydrographic network is practically non-existent because there are no rivers, streams, or ravines in the area. The closest river is the Guá, which is 6.5 km away. From the climatic point of view, accumulated rainfall values are considerably lower than in other areas of the municipality, particularly in the period 2016-2017, where rainfall has been insignificant, with the highest amount recorded in the months of July and August with annual average values of 1000 mm. The average annual evaporation fluctuates between 1800 and 2200 mm and the average temperature is 27 C0, the predominant wind speed is between 3.6 and 5.3 m/sec.

The present forest formation is a semi-deciduous forest on limestone soils. The forests belong to the classification of planted productive forests, categorized as timber producers; the area's vegetation is mostly arboreal, made up of species of timber interest, among the main ones are *Albizia procera (Roxb.) Benth* plantations. (Indian carob tree), *Albizia lebbeck* (L.) *Benth. (Carob tree), Leucaena leucocephala (Lam.) de Wit*

(Leucaena), *Swietenia macrophylla King. x Swietenia mahagoni L. Jacq. (Hybrid Mahogany), Caesalpinia cubensis Greenm. (Yarua), Cordia gerascanthus L. (Baria), Cedrela odorata L. (Cedar*) and *Bambusa vulgaris Schrad. ex J.C. Wendl. (Bamboo).*

The fauna present in the area is characteristic of coastal areas and is distributed according to local conditions and the availability of food and water. As well as, vertebrates,

among which the birds that nest in trees, different reptiles such as lizards of the genus Anolis, and mammals a little less frequent than the previous groups, although several types of domestic livestock such as cattle, pigs, sheep, goats and horses for human feeding and the development of various activities such as transportation.

General description of the field work
The work was carried out in three main stages (Table 1).

Tabla 1. Etapas de trabajo investigativo.

Etapa	Objetivo	Tareas
I. Evaluación dasométrica	Evaluar los parámetros dasométricos de las masas (individuos con más de 5 m de altura total)	1.1. Levantamiento de la información disponible en el Proyecto de Ordenación sobre las masas 1.2. Rodalización del lote con apoyo en la información cartográfica disponible 1.3. Levantamiento de las parcelas de muestreo
		1.4. Caracterización físico – geográfica del sitio 1.5. Estimación de la altura 1.6. Medición del diámetro
II. Clasificación de surtidos	Clasificar los surtidos maderables primarios mediante un despiece comercial	2.1. Selección de los árboles por especie y por clase diamétrica 2.2. Cálculo de los volúmenes por surtidos por especie
III. Valorización de las masas	Valorar comercialmente las masas en pie	3.1. Cálculo del valor de los surtidos 3.2. Identificación de las fuerzas positivas o favorables y las contrarias para el uso futuro del lote

The stands studied were composed of seven forest species of economic interest. Their participation confirms the analysis made so far, so Lot 16 La Demajagua is an area characterized by four well-defined plantations of *A. lebbeck, C. gerascanthus, A. procera* and *Sw. macrophylla x Sw. mahagoni,* as well as the presence of three other species that form small plantations: L. *leucocephala), C. cubensis* and C. *odorata.*

The statistical processing of the results was carried out using the SPSS 19.0 for Windows package version 19.02. The main central tendency and dispersion statistics were carried out: median, mode, maximum, minimum and standard deviation, with the aim of achieving an overall view of the results obtained. Different variables were summarized in percentage terms, to observe how some variables (assortments in this case) were distributed by different categories.

Procedure for evaluation of dasometric parameters

Firstly, a non-standardised interview was carried out, aimed at the technicians of the Silvicultural Based Enterprise Unit of Manzanillo (UEBSM), consisting of open questions whose essential objective was to characterise the entity and its heritage through the

Management Project, as well as to select the sampling method and its intensity. The sampling was simple random, using plots of 20 m by 25 m (500 m2) that were randomly distributed based on the criteria of several authors. Thus, the sample size was determined through the following mathematical expression, where: t is the Student t, S the variance and E: standard error.

$$N = \frac{(t^2 s^2)}{E^2} \quad (1)$$

In order to discriminate the reliability of the sampling, one of the assumptions of normality was tested with the performance of the Streamline Test. The estimated or measured dasometric parameters were as follows: age, which was estimated by the indirect method, by taking the planting date from the records of the UEBSM Management Project, (2007); height, measured by the direct method using a Suunto Hypsometer where one measurement was made at the base and another at the top of the tree (they were added when the horizontal visual was between the base and the top, and subtracted when it was below the base or above the crown); and diameter, which was measured by a direct method, using a tape measure that extended around the entire

circumference of the shaft, at the height of 1.30 m.

Procedure for the classification of wood assortments

Before classifying the primary wood assortments of the masses, and with the dasometric data obtained from the previous stage, a database was created, which allowed the calculation of the different volumes needed on the wood stocks. Next, the average annual increment (AAI) and the periodic increment (PI), considered as the average periodic growth when the period comprises the age of the tree, where Vk was the volume of the year *k* and *k* was the age of the stand, *Y* was the dimension considered, t the age and n the period of time.

$$IMA = \frac{Vk}{k} \quad (2)$$

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

Finally, the indirect method of determining the prices of standing forest products was used to classify the assortments, where costs were not considered, but only the price set by the national industries.

This method uses a commercial classification or commercial cutting of the products that the forest delivers to the feller. It consists of reducing all these products to coefficients, so the cutting consisted basically of three tasks: a representative sample of the

total trees in the class was chosen by diameter class, then the trees chosen were turned over, and the products that could be obtained from them were

quantified, then these partial productions were reduced to coefficients of the total production.

Procedure for estimating the value of production

The estimation of the value of the productions was made considering the average historical prices determined

by Cruz, (2010) from the official lists of the Ministry of Agriculture from 2000 to 2015, and which are summarized in the following table. (Table 2).

Tabla 2. Precios históricos promedios de los surtidos maderables primarios.

Tipo de maderas	Precio por surtido (en moneda nacional)		
	Leña	Rolliza	Bolo
Preciosas	-	62,00	145.00
Duras	14,00	62,00	145,00
Semiduras y Blandas	14,00	25,00	82,00

RESULTS AND DISCUSSION

Dasometric behaviour of masses

Firstly, with respect to the quantity of the stands, it can be said that the number of trees per hectare is high for all species, since the plantations were established by entities whose social purpose was not forest production, and therefore the technical criteria necessary for reforestation with wood species were not followed; Thus, the plantation frames ranged from 1 m x 1 m to 2 m x 2 m, which favored the primary growth (in height) of the species due to its high density, as opposed to its secondary growth (in thickness), which was limited by the lack of maintenance and necessary

silvicultural treatments, mainly thinning.

However, the negative has been the lack of thinning after 10 years of establishing the masses. In general, the thinning should have been carried out in order to increase the living space of the promising specimens in each intervention, maintain the cup index in the range corresponding to the average diameter of the standing mass, obtain the maximum of the high-quality volume (without knots or defects) that the site and the species could give according to the preferential

production defined for each species in the mass.

With respect to the height of the individuals per species in the plantations, and considering their average values, it can be affirmed that the totality of the masses is in a latitudinal stage, specifically in the low latitudinal stage, since the average heights oscillate between 5 and 14 m. (Figure 1).
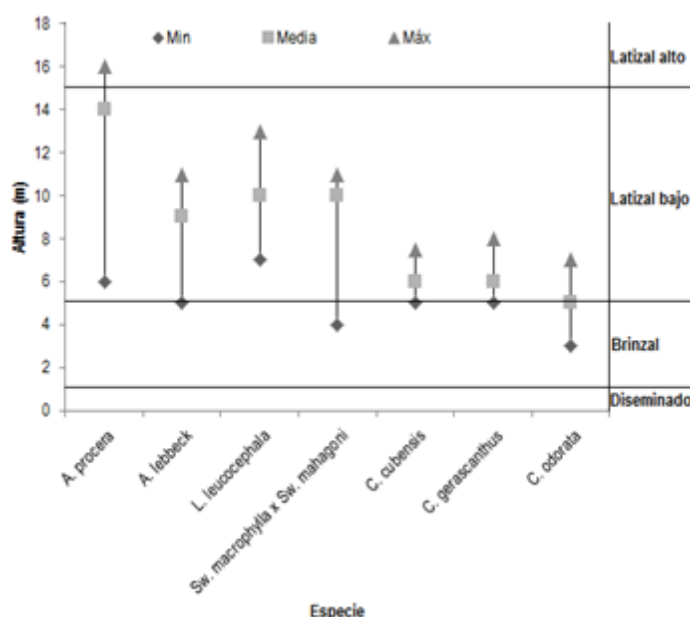

Fig. 1. Comportamiento de la altura.

As can be seen, the species that have grown fastest are *A. procera* and *L. leucocephala*, which in the case of the former have individuals with heights that place them in higher stages of growth; and, on the other hand, the one that has shown the slowest growth in height is *C. odorata,* which means that many individuals have not yet passed the sapling stage.

Other authors report that, (2008) *C. odorata* can be considered as a colonizing species, since it showed better yields in sites with deep and well-drained soils in areas with other tree species and large size, which reflected their tolerance to shade in their juvenile stage, so they accelerate their growth in height if they are limited to abundant sunshine.

The diameter, on the other hand, showed average values that corresponded to the growth stages defined previously for each species, however, it had a different behavior to the height. As can be seen (see Figure 2), the average was around 15 cm, with *L. leucocephala* and *C. cubensis* below this, while *A. lebbeck* and *C. odorata* exceeded 20 cm in average diameter, which could be related to the larger planting frames and ecological conditions referred to.
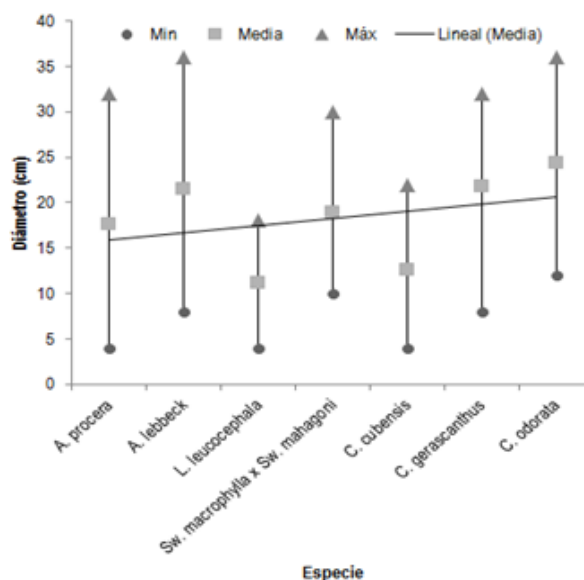
Fig. 2. Comportamiento del diámetro.

Keeping the diameter growth stable and avoiding that the slenderness index increases at the cost of the loss of robustness, is an element to take into account in the management of pure and contemporary plantations, which in this case was not taken into account, and was treated by authors such as Centeno, (2017), who reports it in their results for C. odorata in the conditions of Mexico, as well as Padilla, (2017) for Acacia mangium Willd, in Pinar del Rio, Cuba. The minimum and maximum extremes of the diameters led to a range of diameter classes that extended from 4 cm to 38 cm, this variety is also related to the lack of treatments analyzed above, because in the thinning are applied principles of positive selection to favor, in each intervention, the desirable outstanding that should remain standing, seeking robustness, vigor and intensity of growth of the mass; criteria that coincide with the proposals of Ávarez, (2007) in its classification of timber species for integrated forest management in Cuba.

Standing timber stocks

In the analysis of the condition for the valuation it was obtained that, the order of appearance of two values of a variable was random, being the streak a sequence of similar observations (Table 3). In this way, the total number of gusts was much lower than expected, with strong indications that the variables that determined the volume appear in clusters or groups.

Tabla 3. Resultados de la prueba de rachas.

	Sitio de evaluación
Prueba de valor[a]	10,00
Casos < Prueba de valor	14
Casos > Prueba de valor	18
Total de casos	32
Número de cuartiles	10
Z	-2,283
Asymp. Sig. (2 – tailed)	,022

a. Media

The defined sample size was N = 2, i.e. with only two plots raised it was significant for this investigation, however, four plots were made to increase the reliability of the results of the forest valuation. The information analyzed, in this case the volume variable, met the assumptions of randomness, and it was possible to accept the hypothesis at a level of significance '0.05', i.e. that there were indications that the volume samples were random.

Once the condition for the valuation was established, the plantation timber stocks were estimated, which in total amounted to 286.8 m^3 of standing timber with an approximate distribution of 1.74 m^3/ha; where A. lebbeck (118.18 m^3) and C. gerascanthus (79, 37 m^3) were the species with the highest total volumes and the lowest C. odorata (2.00 m^3),

C. cubensis (4.93 m^3) and L. leucocephala (7.80 m^3).

These results are in correspondence with the area they occupy in the lot and the behavior of the parameters height and diameter, on which the volume depends. It was also evident in the area that logging was done with high thinning criteria, a very negative practice in the maintenance of timber stocks and their preparation to yield the preferential productions in their established shifts.

The IMA is closely related to the analysis carried out previously on timber stocks, so following the criteria of other authors, who state that the maximum thinning is achieved at the time when the greatest growth is achieved, due to the least number of trees; it can be inferred that this is a key element for the commercial planning of the stands (Figure 3).
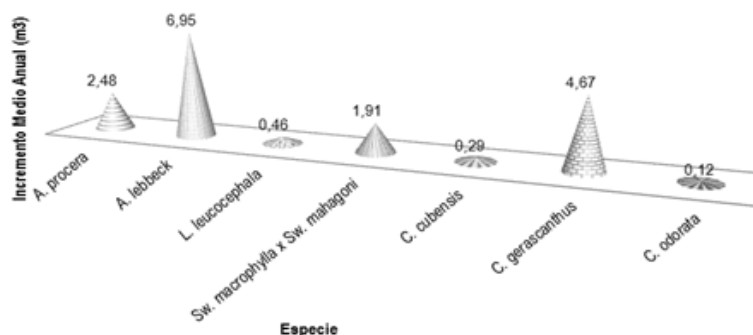
Fig. 3. Incremento medio anual de las especies.

In figure #4, the IPs are represented, mathematically the increase in normal volume of a forest species, in agreement with what was exposed by diverse authors in epidemiometric investigations, is represented by a straight line whose equation of the slope is of the type (Figure 4).
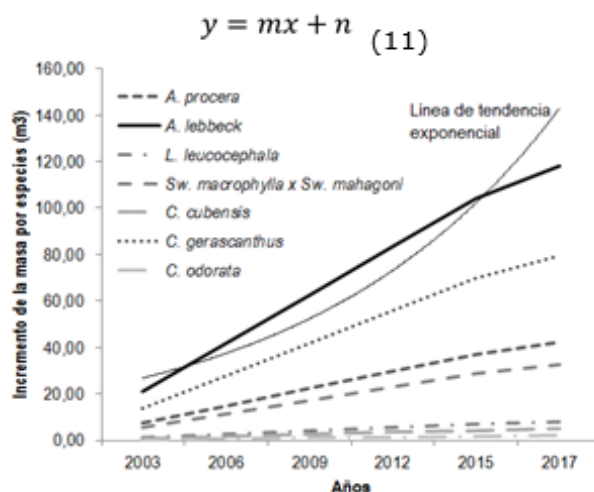

$$y = mx + n \quad (11)$$

Fig. 4. Incremento de la masa por especie.

However, other authors report that the growth of trees, and consequently of forests, is intimately associated with the time factor and the environmental conditions of the site, especially in the tropics.

Therefore, it can be inferred that when environmental conditions (soil and climatic characteristics) are favorable, they express their maximum growth capacity. In this case, the growth curve presents the characteristic behavior reached in each of the phases of the tree's development and the typical variations in the growth rate for each of them.

In this way*, A. lebbeck* and *C. gerascanthus*, were the ones with the highest IP, which is related to the surface occupied by these masses, unlike the rest of the species that dominate less surface, especially *C. odorata, C. cubensis* and *L. leucocephala*, limited in quantity of total heritage. On the other hand, PIs take the form of exponentials.

From commercial species

From a commercial point of view, it is vitally important to describe the assortments that the plantations of La Demajagua can currently generate, as forests of the producer category, so that the UEBSM can adequately plan their use and the possible reimbursements for sales of timber products generated by them.

Firstly, the commercial quartering of the masses with the largest stocks of wood is presented, where it can be seen that the predominant assortments among the four species are made up of Bolus 1 wood (with 306.77 m^3), followed by Bolus 2 wood (with 63.47 m^3), a very positive aspect for the future plans for the use of these species, and in correspondence with the preferential productions of the same, established as sawn timber for industry (Figure 5).
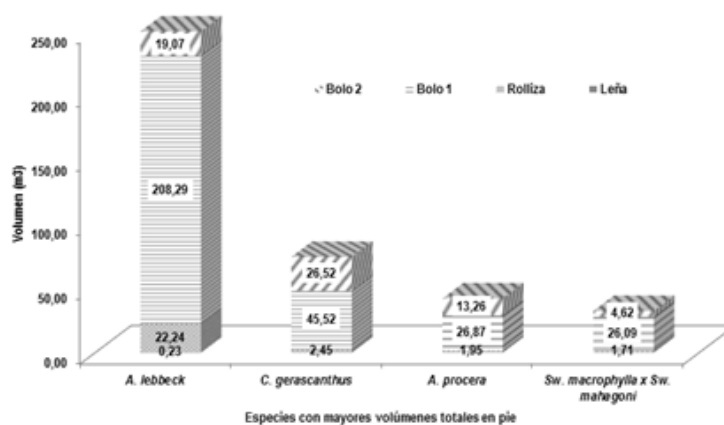

Fig. 5. Despiece comercial de las especies con mayores existencias.

However, of the four species with the highest availability of sawn timber, two are carob trees (*A. lebbeck* and *A. procera*), with very low quality in their wood, which would not meet the needs of the primary and secondary processing industry, mainly wood for different squares and carpentry items in high demand, as it has the disadvantage of low durability.

On the other hand, the three species with less availability showed more variety of assortments to obtain, which is integrally positive, however, considering that for *C. cubensis* and *C. odorata* the preferential production is

bolus wood, the greater availability should be towards this assortment, and only in the last one a greater availability is achieved for both Bolus 1 and Bolus 2. In the case of *L. leucocephala*, whose preferential production is Roundwood, a greater availability of this assortment is evident in the mass, although there is a group of trees that have passed the cutting shift, which indicates the immediate need for intervention to harvest the assortments foreseen in the initial investment. The commercial cutting of the stands can be summarized in the coefficients of the total production of the assortments by species (See figure 6). The results indicate that, independently of the

absence of silvicultural treatments carried out on the stands, in the majority of the species there is a predominance of preferential production with high coefficients, with emphasis on *C. odorata*, *C. gerascanthus* and *Sw. macrophylla x*

Sw. mahagoni, with more than 95% of the stands providing the desired assortments, although all of them present a favourable situation towards the generation of the assortments of their main production.
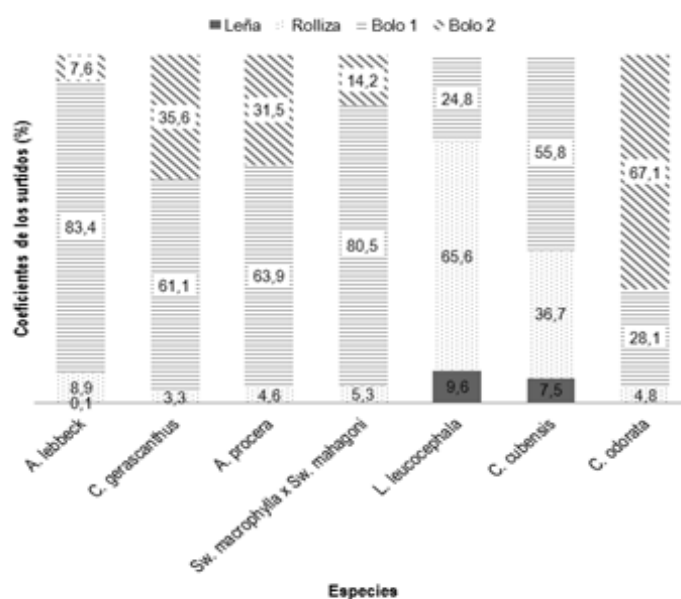

Fig. 6. Coeficientes de la producción total por especies.

Valorization of the masses

Of the estimated value of production by assortment for each species, the highest amount of income is provided by assortments of sawn timber, such as logs and pins 1 and 2. Among the species with the largest stocks (see Figure 7), *A. lebbeck* will yield a total of 19 202.74 CUP, with logs providing the largest contribution with 17 079.78 CUP. It was striking that in this group *Sw. macrophylla x Sw. mahagoni* is the one that can give less income (4 558,97 CUP), species that still must extend its turn to maximize yields, since more than 3 000 CUP at present is being generated by the Rolliza, production that is subordinate to the

preferential, which is the bolus wood. For their part, the species with the smallest stocks total 1 051.37 CUP, with Rolliza being the assortment to be obtained from *L. leucocephala* and *C. cubensis*, as well as Bolus Wood 1 from *C. odorata*. Similarly, it is inferred that there is a need to lengthen the harvesting shift for *C. odorata* and *C. cubensis*, since according to other authors, technically, there is no justification for the fact that sustainable forest management and commercial timber harvesting cannot be achieved in tropical forests through improved practices, in order to reduce the damage resulting from extraction and ensure that harvesting and regeneration are reciprocally balanced.
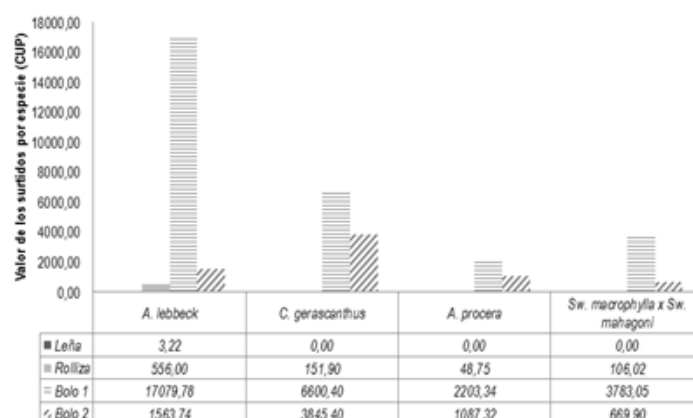
	A. lebbeck	C. gerascanthus	A. procera	Sw. macrophylla x Sw. mahagoni
▪ Leña	3,22	0,00	0,00	0,00
▨ Rolliza	556,00	151,90	48,75	106,02
▤ Bolo 1	17079,78	6600,40	2203,34	3783,05
⁄ Bolo 2	1563,74	3845,40	1087,32	669,90

Fig. 7. Valor estimado de la producción de las especies con mayores existencias.

Finally, after the valuation of the stands, it can be said that the planted forest in La Demajagua can be used for timber so that the UEBSM can repay the investment, starting with the stands whose preferential production is already at maximum yield.

In summary, it is proposed: the total cutting of the stands of *A. lebbeck, A. procera* and *L. leucocephala;* the thinning for the low and long term management of the plantations of *C. odorata, C. gerascanthus, Sw. macrophylla x Sw. mahagoniy C. cubensis*, with the purpose of changing the use of the whole lot, from a producer forest to a conservation forest in the category of Recreational Forest, based on the exposed in Article 25 of Chapter IV of the Forest Law (1998): "(...) are those located in (...) tourist centers and facilities and their peripheries, (...). Their main function is recreational and environmental sanitation".

The number of trees per hectare is high for the seven species that make up the Capital Flight, which is in the grassland stage, denoting the lack of silvicultural treatments since its establishment until today, with *A. lebbeck* and *C. gerascanthus* being the species with the largest timber stocks in the stands, and the smaller *C. odorata, C. cubensis* and *L. leucocephala*.

In most species, preferential productions with high coefficients predominate, with emphasis on *C. odorata, C. gerascanthus* and *Sw. macrophylla x Sw. mahagoni*, independently of the absence of silvicultural treatments.

Assortments of sawn timber, such as logs and boluses 1 and 2, will contribute most to income during the repayment of the investment, which can be maximized by the total cutting of the stands of *A. lebbeck, A. procera* and *L. leucocephala*, and the thinning under *C. odorata, C. gerascanthus, Sw. macrophylla x Sw. mahagoni* and *C. cubensis*.

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