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CARBON MEASUREMENT OF THE NATURAL FOREST ARBOREO STRATUM, TINAJILLAS-LIMON INDANZA

MEDICIÓN DE CARBONO DEL ESTRATO ARBÓREO DEL BOSQUE NATURAL TINAJILLAS-LIMÓN INDANZA, ECUADOR

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Abstract

The objective of this research was to analyze the monitoring of good livestock practices of small and medium milk producers in the province of Carchi, with a entailment project under an inter-institutional agreement between the Salesian Polytechnic University, the Alpina Foundation and the Provincial Autonomous Decentralized Government of the Carchi (GADPC). Two samplings were carried out at 630 productive units to determine the hygienic, sanitary and physico-chemical quality of the milk. With the results of the first phase, a technical intervention was made to the farmers through field visits, lectures and technical advice for the diagnosis of mastitis and integral quality of the milk. In the next phase of the project, the second sampling was carried out where laboratory tests were applied such as pH, cryoscopy, lacto fermentation and reductase. The most relevant results of the study were; in terms of compositional quality, more than 90% of the producers comply with the NTE INEN 9 standard for raw milk; it was also observed that 6.3% of the farmers improved the hygienic quality with bacterial counts <600,000 IBC / ml; in sanitary quality there was no improvement in the reduction of somatic cell contents.
Keywords: Forest, climate change, Carbon, Forestry species, gases of the greenhouse efect.

Resumen

El objetivo de esta investigación fue analizar el seguimiento de las buenas prácticas pecuarias de pequeños y medianos productores de leche de la provincia del Carchi, con un proyecto de vinculación bajo convenio interinstitucional entre la Universidad Politécnica Salesiana, Fundación Alpina y el Gobierno Autónomo Descentralizado Provincial del Carchi (GADPC). Se realizó dos muestreos a 630 unidades productivas para determinar la calidad higiénica, sanitaria y físico- química de la leche. Con los resultados de la primera fase se realizó una intervención técnica a los productores mediante visitas de campo, charlas y asesoramiento técnico para el diagnóstico de la mastitis y calidad integral de la leche. En la siguiente fase del proyecto se procedió a realizar la segunda toma de muestras donde se aplicaron las pruebas de laboratorio como pH, crioscopía, lacto fermentación y reductasa. Los resultados más relevantes del estudio fueron; en cuanto a calidad composicional más del 90 % de los productores cumplen la norma NTE INEN 9 para leche cruda; se observó también que el 6.3 % de los ganaderos mejoraron en la calidad higiénica con conteos bacterianos <600.000 IBC/ml; en la calidad sanitaria no hubo una mejora en la reducción del contenidos de células somáticas.
Palabras claves: bosques, cambio climático, carbono, especies forestales, gases de efecto invernadero.

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1 Introduction

Climate change is a phenomenon that alters the behavior of different ecosystems globally. This change is attributed to human activities and natural causes, highlighting a predominance of the former; from which, there are several effects that derive, such as the increase in climatic events, these are droughts and intense rainfall (Riebeek, 2005). For its part, greenhouse gases (GHGs) also increase, mainly carbon dioxide (CO_2) produced by human activities, fossil fuel consumption, deforestation and land use change. At the same time, there are some peculiarities that generate climate change such as: the general and gradual increase in temperature, changes in rainfall behaviors and increase in extreme events (IPCC, 1995).

One way to mitigate these effects is the CO_2 de absorption capacity of the atmosphere and fix the carbon in the forest biomass, which happens through the process of photosynthesis (FAO, 2006; Yáñez Sandoval, 2004). Therefore, forests play an important role, taking into account that vegetation and soil exchange approximately 80 % of carbon with the atmosphere. Thanks to this process, they store quantities of carbon in the biomass of their leaves, branches, stems and roots, while releasing oxygen into the atmosphere, acting as carbon sinks (Pardos, 2010).

The stored carbon is found in the biomass of the trees and corresponds to the organic matter produced in a forest, standing out four types of biomass: living biomass, underground biomass, dead organic matter and biomass in the soil (FAO, 2002), variables which are considered in the present investigation, in order to determine the volumes of carbon stored in forest ecosystems.

The importance of carrying out this type of measurements in natural forests to determine the carbon stored is that they play a crucial role in the environment because of the services they offer. Among the most significant are: the protection of watersheds, hydrological services, carbon capture, landscape beauty, biodiversity (Robertson y Wunder, 2005).

2 Materials and methods

2.1 Location of the study area

The forest is located to the south of the Eastern Cordillera of the Andes, in the Limón Indanza canton, province of Morona Santiago, it contains 118 ha and includes the plant formations Evergreen montane forest and evergreen low montane forest.

2.2 Stratification of the study area

The area was delimited from topographic maps. The perimeter was defined by georeferencing, using tools from the Geographic Information System and cartography, supported by GPS equipment, interpretation of satellite images and aerial photos. For the stratification the "Guide for the determination of carbon in small rural properties" was applied (Rügnitz Tito et al., 2009) which considers the fundamental factors as: areas with similar management practices and history of land use, soil characteristics, microclimate, relief, existing tree species, state of forest maturity, among others, which affect the amount of carbon, preliminary stratification and preparation of the stratification map of the area.

2.3 Determination of the design of the sampling site

For the definition of the type and sampling design, the following procedure was followed:

2.3.1 Type of plot

Sampling technique was used, installing Permanent Sampling Plots (PPM), for being more efficient and for making future measurements (Corral-Rivas et al., 2013), In order to determine the dynamics of the forest in its natural state, with respect to carbon fixation.

2.3.2 Sampling design

A conglomerate was installed, consisting of 4 plots of 60 x 60 m, placed in the shape of an "L" (Figure 1), giving an area of 14 400 m^2, spaced 250 m apart. The conglomerate was implemented for an area of 100 ha, as indicated in the Field Manual for the National Forestry Evaluation 2012 (MAE, 2012).

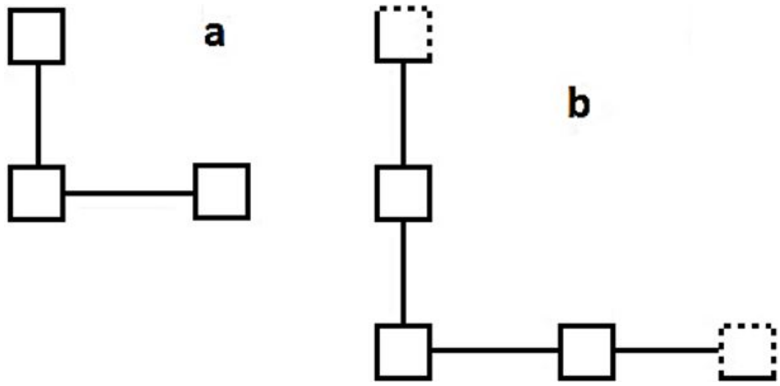

Figure 1. Conglomerate design in the shape of "L"

2.3.3 Measurement of the plots

The plots were measured with respect to a horizontal plane. Because the terrain has an irregular topography, the Slope Correction Factors, established by the United Nations Food and Agriculture Organization-FAO (FAO, 2004), were applied. The plots were installed applying the Arcgis and GPS program, whereby the location was identified and the central point of each plot was determined in order to have the reference to establish the form and limits of each unit of measurement.

2.3.4 Installation of the plots

The plots were projected using the belt or rail method (FAO, 2015a) as shown in Figure 1. These plots were subdivided into 3 lanes of 20 x 60 m each.

2.3.5 Edge effect of the parcels

To avoid the edge effect, the trees that were found within the plot were measured, starting at 10 m from its central axis and the trees located outside this distance were not considered, with this, it was ensured that the trees did not are near the outer edge of the forest.

2.4 Forest measurement

The DAP was measured with bark at 1.30 m, from 10 cm. The measurement consisted of starting from lane 1 of the first subplot of 20 x 60 m.

To determine the biomass, carbon and CO_2, the following estimations were made:

2.4.1 Estimation of the basal area

The basal area was calculated applying the following formula:

$$AB = \frac{\pi}{4} \times DAP^2 \qquad (1)$$

Where:

AB = basal area, m^2.
$\frac{\pi}{4}$ = constant 0,7854.
DAP^2 = diameter at chest height, m

2.4.2 Volume estimation

The volume was determined by the following formula:

$$Volume = AB \times H \times ff \qquad (2)$$

Where:

AB = basal area, m^2.
H = total height of the tree, m.
ff = orm factor (Broadleaves: 0,5).

2.4.3 Estimation of forest biomass

Biomass is a major element in determining the amount of carbon stored in the forest (FAO, 2015b). The forest biomass, discloses the global carbon cycle, which is an important element for studies of climate change. This estimate was obtained from the multiplication of the volume of the forest, the density of the wood, the expansion factor of aerial biomass and the expansion factor of underground biomass.

In accordance with the Guidelines of the Intergovernmental Panel on Climate Change, the applied expansion factor was 1.20 for aerial and underground biomass (IPCC, 2006). The value used for the density of wood was 0.5 (Brown y FAO., 1997; IPCC, 2006) The value of the biomass, was obtained by the following formula:

$$Bf = Volume \times GE \times FEBa \times FEBs \tag{3}$$

Where:

Bf = forest biomass, t.
GE = density of wood, t/m^3 [0,5].
FEBa = Aerial biomass expansion factor (branches,leaves) [1,20].
FEBs = expansion factor of underground biomass (roots) [1,20].

2.4.4 Estimation of carbon stored in the forest

The carbon stored was calculated from the forest biomass data of the area and the carbon fraction of 0.5 was applied, assuming that 50 % of the weight of the individuals is carbon (IPCC, 1995). The formula for obtaining the stored carbon value is:

$$C = B \times Fc \tag{4}$$

Where:

C = carbon in tons of carbon.
B = biomass.
Fc = carbon fraction [0,5].

2.4.5 Estimation of CO_2 stored in the forest

One ton of carbon equals the sequestration of 3.67 t of CO_2. To establish the amount of CO_2 stored from the amount of carbon, the formula was applied:

$$CO_2 = C \times 3,67 \tag{5}$$

Where:

CO_2 = amount of carbon dioxide captured in tons of CO_2.
3,67 = fraction that is used to convert carbon into tons of CO_2.

2.5 Identification of species

2.5.1 Collection of samples

Samples were collected and coded in the field, with common name and specifications. Samples were collected in fertile state with flowers or fruits to facilitate identification. As part of the collection, a photographic record was developed.

2.5.2 Treatment and determination of samples

The samples of the collected species were put in a press and this in turn was placed in a drying chamber. The identification of the samples was carried out with the support of the Herbarium of the University of Azuay (UDA).

2.6 Importance value index by species

The Importance Value Index by species, is a structural synthetic index, developed mainly to rank the dominance of each species in stands. The IVI can fluctuate from 0 to 3.00 (or 300 %). By dividing the IVI by 3, you get a figure that fluctuates from 0 to 1.00 (or 100 %). This value is known as the percentage of importance. The importance value, or percentage of importance, provides a global estimate of the importance of a plant species in a given community, (Zarco-Espinoza et al., 2010), the formula is:

$$IVI = Relative\ Dominance + Relative\ Density + Relative\ Frequency \tag{6}$$

3 Discussion and results

3.1 Composition of the arboreal stratum

The natural forest Tinajillas, is in an active process of succession, as a reaction to the constant disturbances of both natural and anthropogenic nature. In the first case, the reasons are due to the fact that the forest, when found on steep foothills, is subject to frequent landslides. The anthropogenic character, is due to the fact that there are strong pressures for colonization processes, implies that the arboreal stratum of the forest has individuals that are surpassing the phase of latizales, towards saplings. The existing species per family, are indicated in the following Table 1.

Table 1. Existing species by family

EXISTING SPECIES BY FAMILY		
FAMILY	**COMMON NAME**	**SCIENTIFIC NAME**
Araliaceae	Pumamaqui	Schefflera morototoni (Aubl.)
Asteraceae	Negrillo	*Critoniopsis sp.*
Brunelliaceae	Bella maría	*Brunellia sp.*
Chloranthaceae	Pururu	Hedyosmum cuatrecazanum Occhioni
Clusiaceae	Achotillo	Vismia acuminata (Lam.) Pers
	Duco	Clusia latipes Planch. & Triana
Cunoniaceae	Sarar	Weinmannia pinnata Linnaeus
Ericaceae	Joyapa	Cavendishia bracteata Ruiz & Pav.
Escalionacea	Capulí	Escallonia paniculata (Ruiz & Pav.) Roem. & Schult
Euphorbiaceae	Motilón	*Hyeronima alchornoides Allemão*
	Palo del diablo	Alchornea latifolia Swartz
Humiriaceae	Chanul	*Humiriastrum sp.*
Lauraceae	Canelo	Ocotea javitensis (Kunth) Pittier
	Jigua	Nectandra reticulata (Ruiz & Pav.) Mez
Melastomataceae	Flor rosada	Tibouchina lepidota Cogniaux
	Palo de agua	*Miconia sp.*
Melastomataceae	Poma rosa	Blakea grandulosa Gleason.
Rutaceae	Limoncillo	Zanthoxylum ekmanii (Urb.) Alain
Meliaceae	Sacha coco	Guarea kunthiana A. Juss.
Moraceae	Guarumbo	Cecropia sciadophylla Martius
Myricaceae	Laurel	Myrica pubescens Humb. & Bonpl. ex Willd.
Myrsinaceae	Jiripe	Myrsine andina (Mez) Pipoly
Myrtaceae	Chimulo	*Eugenia sp.*
Podocarpaceae	Guabisay	Podocarpus oleifolius D. Don ex Lamb.
Rubiaceae	Cebolla	*Elaeagia sp*
Staphyleaceae	Facte	Turpinia occidentalis (Sw.) G. Don
Bombacaceae	Higeron	*Matisia sp.*

The interspecific composition of the test covering an area of 14,400 m^2 is determined by 925 individuals, grouped into 27 species, 27 genera and 22 families and has a wide range of individuals per species, such is the case of *Miconia sp* that yields 323 individuals (35% of the total), while 3 species such as *Blakea grandulosa, Escallonia paniculata, Matisia sp*, have 1 individual. The *Brunellia sp* and *Cavendishia bracteata* species have 2 individuals per ha, which shows that these species are an indicator of rarity.

3.2 Importance value index by species

The 5 species with the highest Importance Value Index are indicated in Table 2.

The most abundant species are: *Miconia sp* with 323 individuals, *Weinmannia pinnata* with 86 individuals, *Clusia latipes* with 72 individuals, *Ocotea javitensis* with 56 individuals and *Zanthoxylum ekmanii* with 52 individuals.

Considering the importance value index (IVI), the most dominant species is *Miconia sp* with a value of IVI equal to 21 %, *Weinmannia pinnata* and *Clusia latipes* with an IVI equal to 7 %, *Ocotea javitensis* and *Zanthoxylum ekmanii* with an IVI of the 6 % The other species do not exceed 5 % IVI.

Table 2. Existing species by family

IMPORTANCE VALUE INDEX (IVI) BY SPECIES								
SPECIES	**Aa**	**Ar %**	**Fa**	**Fr %**	**Da**	**Dr %**	**IVI 300 %**	**IVI 100 %**
Miconia sp.	323	34,92	3	4,35	6,15	23,22	62	21
Weinmannia pinnata Linnaeus.	86	9,3	3	4,35	1,95	7,35	21	7
Clusia latipes Planchon. & Triana	72	7,78	3	4,35	2,27	8,57	21	7
Ocotea javitensis (Kunth) Pittier	56	6,05	3	4,35	2,27	8,57	19	6
Zanthoxylum ekmanii (Urb.) Alain	52	5,62	3	4,35	1,82	6,86	17	6
Absolute Abundance (Aa), Relative Abundance (Ar %), Absolute Frequency (Fa), Relative Frequency (Fr %), Absolute Dominance (Da), Relative Dominance (Dr %)								

3.3 Data analysis

3.3.1 Basal area, m^2

The basal area that contains the forest in its entirety is 2131 m^2, which represents a value of 18 m^2/ha. At the family level, the species with the highest basal area belong to *Melastomataceae* with a value of 8.40 m^2, that is to say, 32 % of the total units of measurement. In the same way, the species with the highest basal area is Miconia sp with a value of 6.15 m^2, which corresponds to 24 % of the total forest species.

3.3.2 Volume, m^3

The total wood volume of the study area has a value of 13 521 m^3, which is equivalent to 115 m^3 / ha. The largest volume is shown in the family Melastomataceae with a value of 49.70 m^3/ha representing 30 %, while the species with the highest volume is Miconia sp. 33.60 m^3 / ha, that is, 20 % of the total.

For the diametric classification, the diameters were distributed in 5 cm intervals generating 9 categories, the results of which are shown in Table 3 and Figure 1:

Table 3. Number of individuals and their volume per diametric class

DIAMETRIC CLASSES			
CLASs	**RANGe**	**INDIVIDUALS**	**VOLUME, m^3**
I	$\geq$ 10 - 15 cm	514	26,94
II	$\geq$ 15,1 - 20 cm	191	25,02
III	$\geq$ 20,1 - 25 cm	98	25,34
IV	$\geq$ 25,1 - 30 cm	52	20,81
V	$\geq$ 30,1 - 35 cm	36	20,88
VI	$\geq$ 35,1 - 40 cm	15	12,17
VII	$\geq$ 40,1 - 45 cm	8	9,3
VIII	$\geq$ 45,1 - 50 cm	5	8,22
IX	$\geq$ 50,1 cm	6	16,42
TOTAL		925	165

Table 3, states that the largest number of individuals, ie 514 (56%), are in class I, giving a volume of 26.94 m^3 . Class II includes 191 individuals with a volume of 25.02 m^3 ; On the other hand, class III with 98 individuals shows a volume of 25.34 m^3 . The first three diametric classes that cover the range of 10 to 25 cm of DAP, have 803 individuals (87%) and yield a volume of 77.30 m^3 (47%). The smallest volume is concentrated in class IX with 16.42 m^3 . These results confirm that the forest is in an active process of plant succession, in which Miconia sp has a preponderant role.

3.3.3 Forest biomass

The total forest biomass is 9751 t, resulting in a value of 83 t/ha. The family with the highest forest biomass is Melastomataceae with a value of 36 t (30%). The species with a significant amount of biomass is *Miconia sp*, with 24 t, indicating 20% of the total.

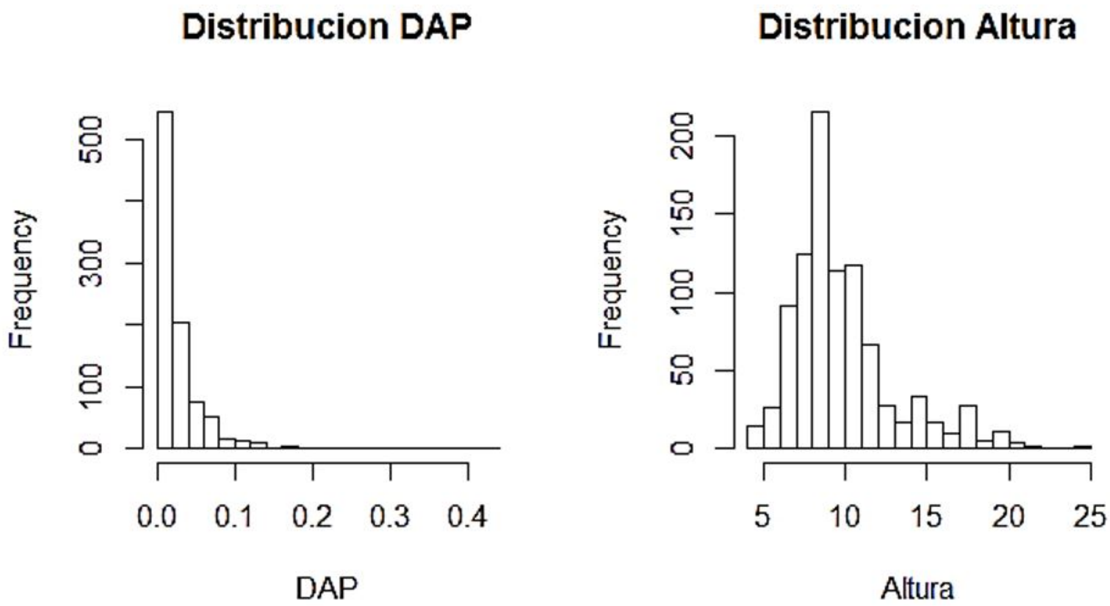

Figure 2. Relationship of the distribution between DAP and height

3.3.4 Stored Carbon

The total carbon stored covers 4835 t/ha and the carbon stored is 41 t/ha. The most representative family is Melastomataceae with an amount of 18 t which corresponds to 31%. The species with the highest amount of carbon stored is *Miconia sp*, with a value of 12 t, resulting in 20% of the measurement units of carbon stored.

3.3.5 Stored CO_2

In the study area the total stored CO_2 is 17 864 t, indicating an amount of 151 t/ha. The family with the most amount of stored CO_2 is *Melastomataceae* with 66 t representing 30% of the study area. The species with the highest stored CO_2 content is *Miconia sp*, with a value of 44 t, which means 20% of the total existing in the CO_2 measurement units, which responds to the large number of individuals present in the study area. On the other hand, as shown in Figure 3, the behavior within the study in terms of carbon and carbon dioxide stored is heterogeneous.

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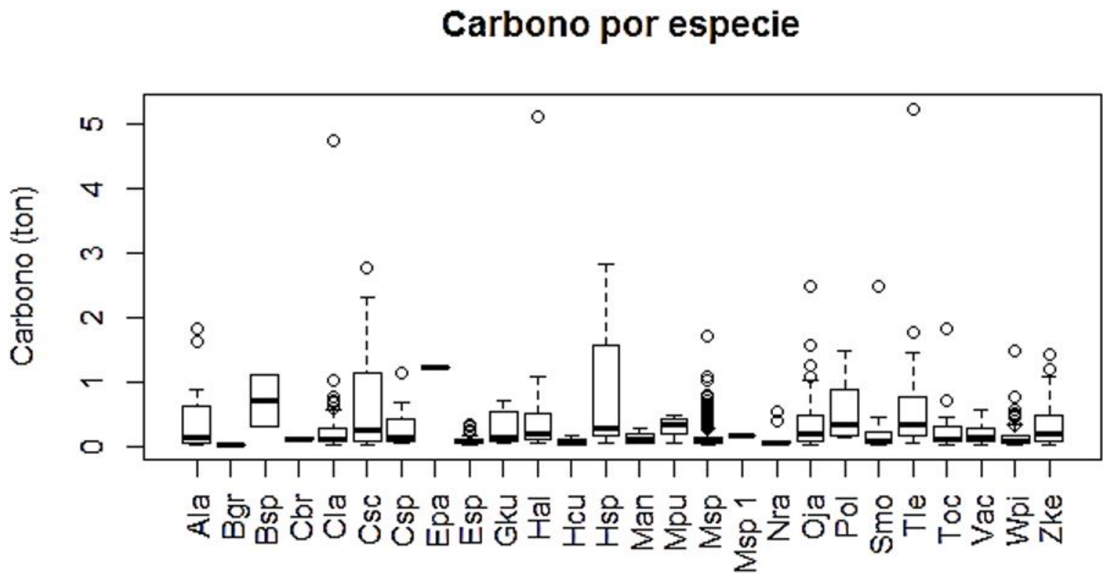

Figure 3. Boxplot of carbon stored by species, following the abbreviation expressed in Table 1

3.4 Statistical analysis of the estimate

In the analysis of the relationship between the DAP variables and the total height of the shaft of the trees and the biomass or carbon stored, it was modeled following the formulas expressed in the methodology and corroborated with the behavior of the biomass as a dependent variable of the DAP.

$$Biomasa \simeq \alpha e^{\beta \times ln(DAP)} \quad (7)$$

Where alpha and beta are coefficients to be estimated from the data, which explain the relationship between biomass (carbon or CO_2) and DAP, according to Li et al., 2017 and other authors, estimates of this type have the behavior aforementioned.

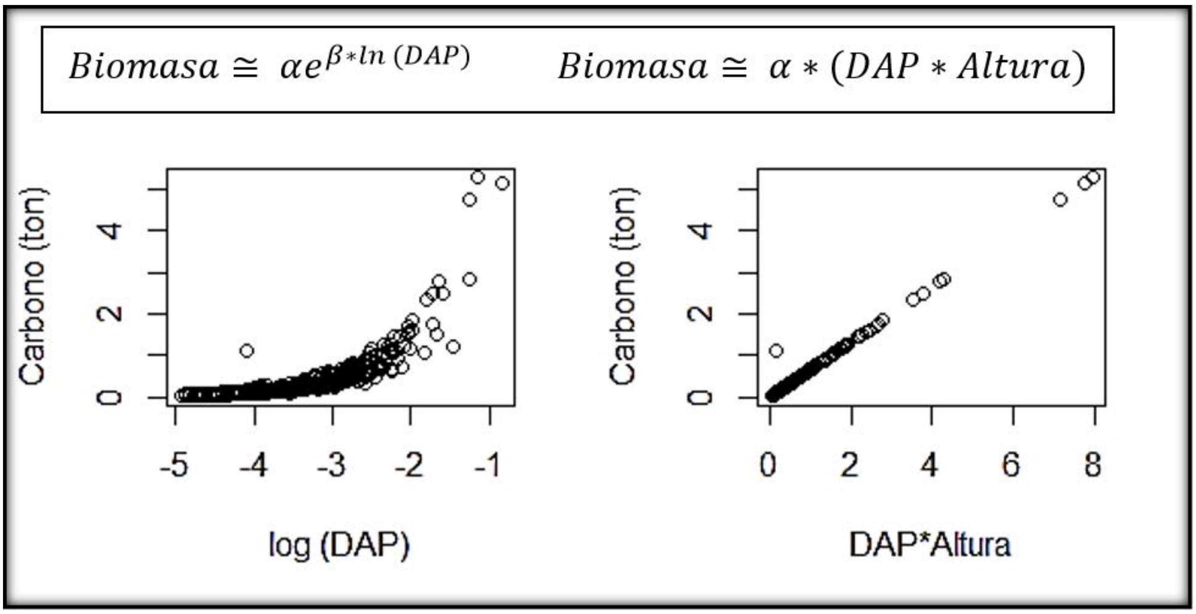

Figure 4. Graphs of the carbon estimation according to the formulas expressed

There is no direct relationship between DAP and the height of the stem, observable in Figure 2. Particularly DAP follows a lognormal distribution so that a direct relationship can not be estimated, however, it is explained with a coefficient almost equal to 1, the relationship between biomass and the interaction between WTP and height as shown in Figure 4. The analysis of the model is shown in Table 4.

Table 4. Estimation of the models presented in Figure 4.

	$\text{Biomass} \simeq \alpha \times (DAP \times Height)$		$\text{Biomass} \simeq \alpha e^{\beta \times ln(DAP)}$	
	Intercept	**DAP×Height**	**Intercept**	**ln (DAP)**
Estimation	0,001249	0,660099	2,74546	1,22168
std Error	0,0012	0,0017	0,0404	0,0101
Probability	0,31	2,00E-16	2,00E-16	2,00E-16
p-value (model)	2,20E-16		2,20E-16	
R^2	0,994		0,9406	

3.4.1 Index - biodiversity analysis

The indices used in the analysis of the measurement of biodiversity are: Shannon - Weinner, Margalef and Simpson, According to the values obtained from the analysis of the three indices, there is a relationship between them, because the result of greater biodiversity and richness coincides between these indices. The 3 species with the most abundant diversity indexes are *Miconia sp, Weinmannia pinnata, Clusia latipes*, as shown below:

Table 5. Statistical analysis for species biodiversity

STATISTICAL ANALYSIS FOR SPECIES BIODIVERSITY				
		INDEX		
Species	**Individuals**	**Shannon - Wienner**	**Margalef**	**Simpson**
Miconia sp.	323	0,53	109	8
Weinmannia pinnata Linnaeus.	86	0,32	29	116
Clusia latipes Planch. & Triana	72	0,29	24	165
Ocotea javitensis (Kunth) Pittier	56	0,24	19	273
Zanthoxylum ekmanii (Urb.) Alain	52	0,23	17	316
Elaeagia sp	43	0,21	14	463
Tibouchina lepidota Cogniaux	34	0,18	11	740
Hyeronima alchornoides Allemão	33	0,17	11	786
Turpinia occidentalis (Sw.) G. Don	31	0,16	10	890
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin	30	0,16	10	951
Alchornea latifolia Swartz	26	0,14	8	1266
Hedyosmum cuatrecazanum Occhioni	26	0,14	8	1266
Vismia acuminata (Lam.) Pers.	24	0,14	8	1485
Critoniopsis sp	18	0,11	6	2641
Myrsine andina (Mez) Pipoly	13	0,09	4	5063
Nectandra reticulata (Ruiz & Pav.) Mez	11	0,08	3	7071
Cecropia sciadophylla Martius	9	0,07	3	10 563
Myrica pubescens Humb. & Bonpl. ex Willd.	9	0,07	3	10 563
Podocarpus oleifolius D. Don ex Lamb.	7	0,05	2	17 462
Guarea kunthiana A. Juss.	7	0,05	2	17 462
Humiriastrum sp.	4	0,03	1	53 477
Eugenia sp.	4	0,03	1	53 477
Brunellia sp	2	0,02	0	21 390 6
Cavendishia bracteata (Ruiz & Pav. ex J. St.-Hil.) Hoerold	2	0,02	0	21 390 6
Blakea grandulosa Gleason	1	0,01	0	85 562 5
Escallonia paniculata (Ruiz & Pav.) Roem. & Schult.	1	0,01	0	85 562 5
Matisia sp.	1	0,01	0	85 562 5
Número de individuos	**925**			

4 Conclusiones

The natural forest flora Tinajillas - Limón Indanza, is composed of a high diversity, represented by 22 families, 27 genera and 27 species. Families with more than one species are: *Clusiaceae*, *Euphorbiaceae*, *Lauraceae*, *Melastomataceae*; the most influential families are *Melastomataceae*, *Clusiaceae*, *Cunoniaceae*, *Lauraceae* and *Euphorbiaceae*. With regard to gender, the most abundant is *Miconia*, followed by *Weinmannia and Clusia*. As for the predominant species, these are: *Miconia sp., Weinmannia pinnata, Clusia latipes*.

The volume of wood existing in the arboreal stratum of the natural forest Tinajillas - Limón Indanza is 115 m^3/ha, represented mostly by the *Melastomataceae* family and the *Miconia sp* species with 35 m^3/ha and 23 m^3/ha respectively.

With respect to the DAP, 9 diameter classes were presented, resulting in class I, which comprises between $\geq$ 10 - 15 cm, which is the one with the highest number of individuals and wood volume, which makes up most of the 514 individuals, resulting in a volume of 18.68 m^3 / ha.

The amount of carbon stored in the Tinajillas-Limón Indanza natural forest study area contains 4,835 t, resulting in 41 t/ha. The family with the largest amount is *Melastomataceae* with 13 t/ha. Likewise, the species with the highest amount of carbon stored is *Miconia sp*. with a value of 8 t/ha.

The CO_2 stored in the Tinajillas-Limón Indanza forest study area is 17 864 t, representing 151 t/ha. Likewise, in the volume, stored carbon and CO_2 content, the family and species with the greatest quantity are *Melastomataceae* with 46 tons/ha of stored CO_2 and *Miconia sp*. with a value of 31 t/ha of CO_2. In class I of DAP the stored CO_2 is 25 t/ha.

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