Carbon capture in living aerial biomass in Tingo María National Park

Captura de carbono en biomasa aérea viva en el Parque Nacional Tingo María

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ABSTRACT

The present research work, has the objective of determining the quantity of carbon in the live aerial arboreal biomass; to do so, seven 50m x 50m plots were defined; randomly distributed within the area of the current research; twenty eight families and seventy three arboreal species were identified from a total of 1837 specimens; the family with the most abundance was Rubiaceae, the specie with the most abundance was Cinchona pubescens Vahl (Quina amarillo) with 143 specimens identified. The quantity of stored carbon in the aerial arboreal biomass was an average of 70.08 tC/ac with respect to the plots studied; statistically, the stored carbon has a heterogenous behavior within the area in study; due to the fact that it is found to be influenced by the height and type of vegetation category; at 1066 – 1187 masl the greatest quantity of carbon was found; and the mature trees influence the quantity of carbon at a 50%, followed by the rest of the categories.

Keywords: carbon, live aerial biomass, absolute abundance, wilderness.

RESUMEN

El presente trabajo de investigación tiene como objetivo determinar el carbono en la biomasa aérea arbórea viva; por lo que se delimitaron 7 parcelas de 50m x 50m; distribuidos aleatoriamente en toda el área de la presente investigación; se identificaron 28 familias, 73 especies arbóreas de un total de 1837 individuos en total; la familia de mayor abundancia fue la Rubiaceae, la especie de mayor abundancia absoluta fue la Cinchona pubescens Vahl (Quina amarilla) con 143 individuos identificados. El promedio de carbono en la biomasa aérea arbórea viva fue de 70.08 tC/ha con respecto a las parcelas de estudio; estadísticamente el carbono almacenado tiene un comportamiento heterogéneo dentro del área de estudio; debido a que se encuentra influenciada por la altitud y categoría de tipo de vegetación; a 1066 – 1187 msnm se halló la mayor cantidad de carbono; y los árboles maduros, influencia un 50% en la cantidad de carbono, seguido del resto de categorías.

Palabras clave: carbono, biomasa aérea viva, abundancia absoluta, zona silvestre.
I. INTRODUCCIÓN

The Intergovernmental Panel on Climate Change (IPCC) (2018) mentions that there is a growing global concern about the increase in the concentration of carbon dioxide (CO2) in the earth’s atmosphere, which is considered one of the six main gases involved in the greenhouse effect (GHG); and that contribute in greater proportion to climate change. One way to reduce CO2 emissions is to capture it, fix it and store it for as long as possible in plant biomass. The main problem, which encourages the realization of the investigation is the increase in temperature within our locality. According to the data obtained from the José Abelardo Quiñones meteorological station (Tingo María), they indicate that from 1940 to 1970 the minimum temperature has increased by approximately 1 °C, likewise until 2005 it had increased by 1.1 °C, for the year 2018 the temperature increased 0.8 °C, so probably the increase in different economic activities and population growth are generating a large amount of CO2, for which the temperature is increasing, because these parameters have a relationship directly proportional. The IPCC indicates that from the 1990s to the present the temperature has been increasing due to the large generation of greenhouse gases due to industrialization, it also reports that the change in temperature greater than 1.5 °C since the world will suffer fewer negative impacts in the intensity and frequency of extreme events, in resources, ecosystems, and/or equal to 2 °C generates large impacts on natural and human systems (IPCC, 2018); Therefore, it recommends maintaining a temperature change of less than 1.5 °C since the present the temperature has increased by approx

Methodology

Determination of the absolute abundance of tree species identified in the forests of the Tres de Mayo – Rio Oro stretch in the wild area of the PNTM

Determination of sample size

A simple random sampling was carried out, for which the error was 15% with a confidence coefficient of 85%, with these data the sample size was determined. Following the standard statistical sampling procedures, the plot size was 0.25 hectares (50mX50m), the following formula was used (Morillas, 2007).

\[
n = \frac{N \cdot \frac{Z_{1-\alpha/2}^2 \cdot \sigma^2}{(N - 1) \cdot E^2 + \frac{Z_{1-\alpha/2}^2 \cdot \sigma^2}{\alpha}}}{\varnothing > 40 \text{ cm}}
\]

Where:

- \( n \) = Number of plots of size 0.25 (Ha)
- \( N \) = Total number of study plots (Ha) (value = 3516.4)
- \( Z_{1-\alpha/2} \) = Value of Z according to confidence level (value = 1.44)
- \( \sigma \) = Variance (value = 0.28)
- \( E \) = Error (value = 15%)

Delimitation of plots

According to Manta (1988), in each of the delimited plots sub-plots were made for the sampling of low poles (2 of 10 x 10 m), tall poles (2 of 25 x 25 m), poles and mature trees in total of the plot (1 of 50 x 50m).

Tree inventory

Table 01.
The categories evaluated in the trees

| Category | Diameter |
|----------|----------|
| low pole | > 1.3m high at Ø < 5cm |
| tall pole | 5cm < Ø ≤ 10cm |
| stem | 10cm < Ø ≤ 40cm |
| mature trees | Ø > 40 cm |

Source: Blanket (1988)

Tree coding and labeling

Each tree species found was coded with mica plates, the coding started from number one until the end of the count, and the plate was placed approximately at the height where the diameter of the tree was measured, likewise the evaluated category was labeled and the sub plot to which it belongs: for low poles (B), for tall poles (L), for poles (P) and for mature trees (A); for this, the nails were used to hold the plates; For this work, the modified label model (Pinelo, 2000) was used.
Species abundance calculation

According to Lamprecht (1990), the absolute abundance (Aa) of a species is expressed by the total number of individuals "ni" of each species existing in the study area:

\[ Aa = \sum ni \]

Where:
- Aa = Absolute abundance.
- \( \sum ni \) = Sum of number of equal species.

Determination of biomass area and carbon stored in tree species in the section Tres de Mayo – Rio Oro in the wild area of the Tingo María National Park

Tree diameter measurement

The diameter of the trees was measured in the bark, at breast height (1.3m), this diameter is called: diameter at breast height (dbh) (Ortiz, 1993), which was measured with a tape measure reinforced (so that the measurement is as accurate as possible).

Tree height measurement

Vallejo et al. (2005) indicates that in order to obtain the height of the trees, the estimation must be made from the ground to the top of the crown of each individual.

For the direct estimation of the heights of the trees, the Blumme-Leiss method was used, it should be noted that when the height is estimated, not much precision is achieved, and an approximate error of up to 1m can be obtained; To determine the error in the height estimation, a control measurement was made with a clinometer to a sample of trees as learning and reduction of the error in the estimation (Domínguez, 2010).

Sample extraction

For each species of tree found within the plot, a sample of wood was collected from the stem of the tree; these samples were cylindrical which allowed studying the humidity and basic density of the forest species, this estimation method is used more frequently for such studies (Borrero, 2012).

Dry weight calculation

A sample of each tree species found was extracted, which was then stored in an official manila envelope to later be dried in an oven at 75°C in the laboratory until the constant dry weight was found and weighed on the scale, precision (Wieman and Williamson, 1989).

Basic Density Calculation

Murray and Jacobson (1982), for the determination of the basic density of the wood, the wood samples were used and it was determined by dividing the green volume submerged in water by the dry weight of the wood.

Calculation of aerial tree biomass

To determine the aerial biomass, an exponential equation established by Chave et al. (2005) referenced below:

\[ BT = \exp(-2.977 + \ln(\delta \times \text{Dap}^2 \times h)) \]

Where:
- BT = Aerial biomass (Kg)
- Ln = natural logarithm
- dbh = Diameter at breast height or DBH (cm)
- h = Total tree height (m)
- \( \delta \) = Basic density of wood (g/cm3)
- 2.977 = Constant

Calculation of stored carbon

After obtaining the biomass, the stored carbon was calculated with the following formula proposed by IPPC (2003):

\[ CA = BT \times 0.5 \]

Where:
- AC = Carbon stored (t C/ha)
- BT = Biomass (t/ha)
- 0.5 = Conventional constant indicated by the IPCC (Carbon).

Determination of the behavior of stored carbon based on altitude and category of vegetation type

Statistical analysis was performed with the help of the IBM SPSS Statistics Trial (Classic student) software, and Microsoft Excel:

Table 02.

Analysis of variance (ANVA)

| Variation Source | Degrees of freedom | Sum of squares | Middle square | F-value |
|------------------|--------------------|----------------|---------------|---------|
| Regression       | k                  | SCR = \sum (Y_i - \bar{Y})^2 | CMR = \frac{SCR}{k} | F = \frac{CMR}{CME} |
| Error            | n – k – 1          | SCE = \sum (Y_i - \bar{Y})^2 | CME = \frac{SCE}{n – k – 1} |         |
| Total            | n – 1              | SCT = \sum (Y_i - \bar{Y})^2 |               |         |

Source: Allen (2001)
III. RESULTS

Determination of the absolute abundance of the tree species identified in the forests of the Tres de Mayo – Río Oro section in the wild area of the Tingo María National Park (PNTM)

Table 03.
Absolute abundance of tree species by evaluated plots.

| Family      | Scientific name                                                                 | Common name          | P1 | P2 | P3 | P4 | P5 | P6 | P7 | oh |
|-------------|---------------------------------------------------------------------------------|----------------------|----|----|----|----|----|----|----|----|
| Annonaceae  | fusaea peruviana RE Fries                                                       | anonilla             | 0  | 0  | two| 0  | 3  | 5  | 5  |      |
|             | Guatteria hyposerceidiols                                                       | Carahuasca           | 0  | 0  | 3  | 0  | 0  | 0  | 2  | 5  |
|             | annona scandens aff. diels                                                       | Yanavarilla          | 17 | 19 | 0  | 0  | 6  | 5  | 24 | 71  |
| Anacardiace | Spondias mombin L.                                                               | ubos                 | 0  | 0  | 0  | 0  | 0  | 0  | 5  | 5  |
|             | Mangifera indica L.                                                             | Mango                | 0  | 4  | 0  | 0  | 0  | 0  | 0  | 4  |
|             | Rhigospira quadrangularis (Muell. Arg.) Miers                                   | Guayavilla           | two| 4  | 3  | 17 | 0  | 0  | 63 |
| Apocynaceae | Apidosperea excelsum aublet                                                      | caspi rowing         | 0  | 0  | 6  | 0  | 4  | 0  | 1  | 16 |
|             | Socratea exorrhiza H. Moore                                                      | Pona                 | 0  | 0  | 3  | 1  | 6  | 24 | 0  | 81 |
|             | maximiliana maripia (Aubl) Drude                                               | Maximilian           | 0  | 0  | 0  | 10 | 0  | 0  | 0  | 10 |
|             | Protium decandrum (Aublet)                                                      | Copal                | 0  | 0  | 0  | 3  | 9  | 6  | 0  | 18 |
| Burseraceae | bursera graveolens HBK                                                          | Lignum vitae         | 7  | 0  | 0  | 0  | 3  | 0  | 25 | 35 |
|             | bixa orellana L.                                                                | achiote caspi        | 0  | 0  | 0  | 0  | 0  | 0  | 3  | 3  |
| Bignoniaceae| Copaia Jacaranda (Aubl.) D. Don                                                  | Huamansamana         | 0  | 0  | 7  | 0  | 0  | 0  | 0  | 7  |
| Caricaceae  | Jacarata digitata(Poepp.) Solms                                                | papaya caspi         | 0  | 0  | 0  | 0  | 0  | 0  | 5  | 5  |
| Caryocarace | Anthodiscus gutierrezii L. Wms.                                                 | jacket               | 0  | 0  | 0  | 0  | 0  | 0  | 2  | 0  |
| Clusiaceae  | Garcinia macrophylla Mart                                                        | chickadee            | 0  | 0  | 0  | 0  | 6  | 5  | 0  | 5  |
| Combretaceae| Terminalia oblongata (Ruiz & Pav.) Steud.                                       | raffle               | 0  | 0  | 0  | 0  | 25 | 0  | 5  | 1  |
|             | Americanis Terminalia (JF Gmelin) Exell.                                        | yacushapana          | 5  | 25 | 0  | 0  | 14 | 10 | 2  | 56 |
|             | Terminalia catappa (L.) Lour.                                                    | Almond               | one| 0  | 0  | 0  | 6  | 3  | 1  | 17 |
|             | Schizolobium amazonicum huber                                                    | Pachaco              | 0  | 0  | 0  | 4  | 0  | 0  | 0  | 4  |
|             | towering inga Mark                                                              | Shimilblo             | 8  | 16 | 23 | 9  | 14 | 9  | 81 |
|             | Sclerolobium melinonii harms                                                     | uchshaquiro white    | 0  | 0  | 0  | 0  | 3  | 0  | 2  | 0  |
| Fabaceae    | Bauhinia guianensis aublet                                                       | ox leg               | 0  | 0  | 0  | 0  | 0  | 0  | 2  | 0  |
|             | Apuleia molaris Spruce ex Bentham                                                | caspi cabbage        | 0  | 0  | 0  | 0  | 0  | 0  | 2  | 0  |
|             | Cassia reticulata Wild.                                                          | Broom                | 0  | 0  | 0  | 0  | 0  | 0  | 2  | 0  |
|             | Balizia pedicellaris(DC) Barneby & JW Grimes                                    | pashaco vilco        | two| 0  | 0  | 0  | 0  | 0  | 0  | 3  |
|             | Erythrina urei harms                                                             | Amasisa              | 0  | 0  | 0  | 0  | 18 | 0  | 0  | 23 |
| Hypericaceae| Viscia cayennensis(Jaquin) Person                                                | Pichirina            | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
|             | Symphonia globulifera L.f.                                                       | sulfur stick         | 0  | 0  | 0  | 0  | 10 | 0  | 0  | 12 |
| Lamiaceae   | Vitis psudolea Rusby                                                             | pali dog             | 5  | 0  | 0  | 0  | 19 | 8  | 4  | 36 |
|             | Amazon Aniba Meiz                                                                | Moena                | 0  | 0  | 3  | 0  | 0  | 0  | 0  | 3  |
|             | Aniba Cinnamon (HBK) Mez.                                                        | cinnamon moena       | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 2  |
| Lauraceae   | Aniba perutilis Hemsley Kew                                                      | black moena          | 6  | 0  | 0  | 0  | 0  | 0  | 10 | 8  |
|             | Persia mollis (Kunth) Spreng.                                                    | moena avocado        | 0  | 0  | 0  | 0  | 0  | 0  | 0  | one|
|             | Mezilaurus synandra (Mez)Koster.                                                 | Moena                | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 2  |
|             | Nectandra capanaahuensiis O. Schmidt                                             | Yellow Moena         | 0  | 0  | 9  | 0  | 9  | 6  | 2  | 36 |

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| Family               | Species                                             | Number of plots | P1 | P2 | P3 | P4 | P5 | P6 | P7 | Average |
|---------------------|-----------------------------------------------------|-----------------|----|----|----|----|----|----|----|---------|
| Lecythidaceae       | american persea Mill                                |                 |    |    |    |    |    |    |    | 26      |
|                     | Eschweileria juruensisKunth                         |                 |    |    |    |    |    |    |    |         |
|                     | Quanaria ochroaclyx (Schumann) Viscer             |                 |    |    |    |    |    |    |    |         |
|                     | Ochroma pyramidal (Cav. Ex Lam) Urban             |                 |    |    |    |    |    |    |    |         |
| Malvaceae           | Matisia cordata Humb, et Bonpl.                    |                 |    |    |    |    |    |    |    |         |
|                     | Bombax paraense duck                              |                 |    |    |    |    |    |    |    |         |
|                     | Heliocarpus americana L.                           |                 |    |    |    |    |    |    |    |         |
|                     | Theobroma subincanum C.Martius                    |                 |    |    |    |    |    |    |    |         |
|                     | Myconia minutifolia frozen                        |                 |    |    |    |    |    |    |    |         |
| Melastomataceae     | Miconia rimachii Wurdack                           |                 |    |    |    |    |    |    |    | 68      |
|                     | Kunthian guarea A. Juss.                           |                 |    |    |    |    |    |    |    |         |
|                     | Cedrela fissilisVell.                               |                 |    |    |    |    |    |    |    |         |
|                     | Cedrela lilloiC.DC.                                 |                 |    |    |    |    |    |    |    |         |
|                     | Brosimum alicastrum Swartz                         |                 |    |    |    |    |    |    |    |         |
|                     | Ficus guianesis Dev.                               |                 |    |    |    |    |    |    |    |         |
|                     | Ficus insipida willd                               |                 |    |    |    |    |    |    |    |         |
| Moraceae            | Pseudo media laevis (Ruiz & Pavon)                 |                 |    |    |    |    |    |    |    |         |
|                     | Claricia racemosa R. and P.                        |                 |    |    |    |    |    |    |    |         |
|                     | Brosimum acutifolium Hubert.                       |                 |    |    |    |    |    |    |    |         |
|                     | Maclura tinctoria(L.) D.Don ex Steud.              |                 |    |    |    |    |    |    |    |         |
|                     | obovate ferrule duck                               |                 |    |    |    |    |    |    |    |         |
| Myristicaceae       | Iryanthera jauensisWarburg                         |                 |    |    |    |    |    |    |    |         |
|                     | Virola sebifera abulet                             |                 |    |    |    |    |    |    |    |         |
| Podocarpaceae       | Podocarpus oleifolius D.Don                        |                 |    |    |    |    |    |    |    |         |
|                     | Cinchona pubescens Vahl                            |                 |    |    |    |    |    |    |    |         |
| Rubiaceae           | Cinchona delessertiana Standl.                    |                 |    |    |    |    |    |    |    |         |
|                     | Cinchona micrantha Wow.                            |                 |    |    |    |    |    |    |    |         |
| Rutaceae            | Zanthoxylum riedelianum Engler                     |                 |    |    |    |    |    |    |    |         |
| Sapotaceae          | Manilkara bidentata (ADC) Chev.                    |                 |    |    |    |    |    |    |    |         |
|                     | bacciferous uretha L. Gaudich                      |                 |    |    |    |    |    |    |    |         |
|                     | Two-tone pourma C.Martius                          |                 |    |    |    |    |    |    |    |         |
|                     | Pouroma ceropiifolia C.Martius                     |                 |    |    |    |    |    |    |    |         |
| Urticaceae           | Cecropia membranacea Trecul.                      |                 |    |    |    |    |    |    |    |         |
|                     | Cecropia utubambana Linn.                          |                 |    |    |    |    |    |    |    |         |
|                     | Cecropia sciadophylla Loefl.                       |                 |    |    |    |    |    |    |    |         |
| Verbenaceae         | Verbena littoralisHBK                              |                 |    |    |    |    |    |    |    |         |
| Vochysiaaceae       | Vochysia vismiifolia Spruce ex Warming             |                 |    |    |    |    |    |    |    |         |

|                      |                                                      | P1 | P2 | P3 | P4 | P5 | P6 | P7 | Average |
|---------------------|-----------------------------------------------------|----|----|----|----|----|----|----|---------|
|                      |                                                      |    |    |    |    |    |    |    |         |

* P1, P2, P3, P4, P5, P6, P7: Number of plots
* Aa: Absolute abundance

Table 03 shows the absolute abundance of the species, likewise the total number of species identified were 1837 individuals as shown in the annexes, resulting in the inventory of 28 identified families, with a variety of 73 species in the 7 plots evaluated in the study. The most abundant family is Rubiaceae followed by the Urticaceae family. The species with the highest absolute abundance is the Cinchona pubescens Vahl (Quina amarillo) with 143 individuals, followed by the Cinchona micrantha Vahl. (Quina) with 116 individuals; the least abundant species was Persea mollis (Kunth) Spreng. (Palta moena), the species Cedrela lilloi C.DC. (Lilac cedar) and the species Cedrela fissilis Vell. (Cedro huausa) with 1 identified individual each.
Table 04.
Basic density of tree species.

| Scientific name                          | Common name         | P(g) | V(cm³) | δ(g/cm³) |
|------------------------------------------|---------------------|------|--------|----------|
| *Fusaea peruviana* RE Fries              | anonilla            | 32.66| 65     | 0.50     |
| *Guatteria hyposericea*                   | Carahuaasca         | 9.22 | twenty-one| 0.44     |
| * annonna scandens* aff. diels            | Yanavarilla         | 3.16 | 3      | 0.53     |
| *Spondias mombin* L.                     | ubos                | 9.3  | 26     | 0.36     |
| *Mangifera indica* L.                    | Mango               | 24.6 | 60     | 0.41     |
| *Rhigospira quadrangularis* (Muell. Arg.) Miers | Guayavilla         | 6.4  | 25     | 0.26     |
| *Aspidosperma excelsum* abllet            | caspi rowing        | 28.71| fifty  | 0.57     |
| *Socratea exorrhiza* H. Moore             | Pona                | 5.14 | twenty | 0.26     |
| *maximiliana maripa* (Aubl.) Druke        | Maximilian          | 2.06 | 6      | 0.34     |
| *Protium decandrum* (Aublet) Marchand    | Copal               | 9.04 | 13     | 0.70     |
| *bursera graveolens* HBK                  | Lignum vitae        | 22.78| 26     | 0.88     |
| *Ochroma pyramidal* (Cav. Ex Lam) Urban  | top                 | 7.1  | 38     | 0.19     |
| *Matisia cordata* Humb. et Bonpl.         | frog                | 5.42 | 13     | 0.42     |
| *Bombax paraense* ducke                   | punja               | 12.49| 31     | 0.40     |
| *bixa orellana* L.                       | achiote caspi       | 10.8 | 26     | 0.42     |
| *Copaija Jacobanda* (Aubl.) D. Don        | Huamansamana        | 11.1 | 28     | 0.40     |
| *Jecarattia digitata* (Poeppl.) Solms    | papaya caspi        | 16.32| 41     | 0.40     |
| *Anthodiscus gutierrezii* L. Wms.        | jacket              | 22.79| 46     | 0.50     |
| *Two-tone pouroma* C.Martius             | Sachavilla          | 6.3  | 18     | 0.35     |
| *Pouroma cecropifolia* C.Martius         | Sachavilla          | 40.85| 118    | 0.35     |
| *Cecropia membranacea* Trecul.           | Cetic               | 4.06 | 12     | 0.34     |
| *Cecropia uctubambana* Linn.             | Uctubamba           | 76.39| 105    | 0.73     |
| *Vismia cayennensis*(Jacquin) Person      | Pichirina           | 7.13 | 14     | 0.51     |
| *Symphonia globullfera* L.f.             | sulfur stick        | 29.58| 57     | 0.52     |
| *Garcinia macrophylla* Mart              | chickadee           | 5.78 | 19     | 0.30     |
| *Terminalia oblongata* (Ruiz & Pav.) Steud. | raffle              | 28.12| 48     | 0.59     |
| *Amazonian Terminalia* (JF Gmelin) Exell. | yacushapana        | 33.64| 51     | 0.66     |
| *Terminalia catappa* (L.) Lour.           | Almond              | 10.13| twenty| 0.51     |
| *Schizolobium amazonicum* huber          | Pashaco             | 11.45| 29     | 0.39     |
| *towinging inga* Mark                    | Shimbllo             | 15.89| 24     | 0.66     |
| *Sclerolobium melinoni* harms            | ucshaqiro white     | 21.61| 55     | 0.39     |
| *Bauhinia guianensis* abllet              | ox leg              | 7.72 | twenty| 0.39     |
| *Apuleia molaris* Spruce ex Bentham      | caspi cabbage       | 20.23| 37     | 0.55     |
| *Cassia reticulata* Wild.                | Broom               | 69.79| 102    | 0.68     |
| *Balizia pedicellaris*(DC.) Barney & JW Grimes | pashaco vilo        | 32.2 | 80     | 0.40     |
| *Erythrina ulei* harms                   | Amasisa             | 15.55| 39     | 0.40     |
| *Amazon Aniba Meiz*                      | Moena                | 22.7 | 43     | 0.53     |
| *Aniba Cinnamon* (HBK) Mez.              | cinnamon moena      | 12.7 | 29     | 0.44     |
| *Aniba perutilis* Hemsley Kew             | black moena         | 9.57 | twenty| 0.48     |
| *persea mollis* (Kunth) Spreng.          | moena avocado       | 31   |       | 0.48     |
| *Meziliauro synandra* (Mez)Kosterm.      | Moena                | 19   | 39     | 0.49     |
| *Nectandra capanahuensis* O. Schmidt     | Yellow Moena        | 5.72 | 10     | 0.57     |
| *American persia Mill*                    | Avocado             | 4.4  | 10     | 0.44     |
| *Eschweileria juruensis*Knuth             | machimango          | 16.26| 24     | 0.68     |
| *Quararibea ochroalyx* (Schumann) Vischer | sapote             | 9.42 | 22     | 0.43     |
| *Theobroma subincanum* C.Martius         | peanut              | 11.41| 23     | 0.50     |
| *Myconia minutifolia* frozen             | piece of paper      | 13   | twenty-one| 0.62     |
| *Miconia rimachii Wurdack*               | Myconia             | 21.2 |       | 0.47     |
| *Kunthian guarea* A. Juss.               | height requirement  | 14   | 23     | 0.61     |
Table 05. Total aerial biomass by category and plot (Kg)

| Category                  | P1       | P2       | P3       | P4       | P5       | P6       | P7       | Total    |
|---------------------------|----------|----------|----------|----------|----------|----------|----------|----------|
| Low slats (100m2)         | 12.69    | 16.45    | 101.35   | 14.61    | 21.08    | 21.30    | 14.94    | 11190.65 |
| High slats (625 m2)       | 266.37   | 370.52   | 896.44   | 150.77   | 670.68   | 422.19   | 175.57   | 16652.39 |
| Stems (2500 m2)           | 4473.34  | 9420.13  | 29206.93 | 7175.95  | 30575.24 | 13282.73 | 9684.11  | 32315.96 |
| Mature trees (2500 m2)    | 6439.25  | 6845.29  | 2111.24  | 74381.65 | 18722.83 | 8201.01  | 5240.29  | 81722.98 |
| Total                     | 11190.65 | 16652.39 | 32315.96 | 81722.98 | 49989.83 | 21927.23 | 15114.91 |

Table 04 shows the basic densities for tree species, and Table 05 shows the total sum of aerial biomass for each plot, of which plot 4 has the highest value with 81 722.98 Kg, followed by plot 5 with 49 989.83 Kg, then there is plot 3, followed by plot 6, also plot 2, penultimate plot 7 with 15 114.91 Kg and finally plot 1 with 11 190.65 Kg. These results were used to calculate the carbon stored by category of vegetation type and respective plot.

Table 06. Carbon stored by category of vegetation and plot.

| Category     | P1      | P2      | P3      | P4      | P5      | P6      | P7      | \( \bar{x} \) |
|--------------|---------|---------|---------|---------|---------|---------|---------|-----------|
| low poles    | 0.63    | 0.75    | 0.82    | 3.34    | 5.07    | 2.50    | 0.73    | 1.98      |
| high poles   | 2.13    | 2.44    | 2.96    | 4.39    | 7.17    | 4.87    | 1.21    | 3.60      |
| stems        | 8.95    | 18.84   | 58.41   | 14.35   | 61.15   | 26.57   | 19.37   | 29.66     |
| mature trees | 12.88   | 13.69   | 4.22    | 148.76  | 37.45   | 16.40   | 10.48   | 34.84     |
| Total        | 24.59   | 35.72   | 66.42   | 170.85  | 110.83  | 50.34   | 31.79   | 70.08     |
Table 06 shows the stored carbon, with an average of 70.08 t of C/ha. According to the category of vegetation type, mature trees store 34.84 t of C/ha, followed by poles with 29.66 t of C/ha, tall poles with 3.60 t of C/ha and low poles with 1.98 t of C/ha. We also observed that the category of vegetation type that stores the most carbon in its biomass is mature trees with 50% of the total, followed by poles with 42%, tall poles with 5% and low poles with 3% for each hectare within the wild zone of the PNTM.

**Determination of the behavior of stored carbon based on altitude and category of vegetation type**

Table 07. Frequency distribution of altitude intervals.

| K  | Xi             | x'i | neither | Neither | hi     | hi     | tC/ha |
|----|----------------|-----|---------|---------|--------|--------|-------|
| one| [822 – 943]    | 882.5 | two    | two    | 0.286 | 0.286 | 28.19 |
| two| [944 – 1065]   | 1004.5| two    | 4       | 0.286 | 0.571 | 51.07 |
| 3  | [1066 – 1187]  | 1126.5| one    | 5       | 0.143 | 0.714 | 170.85|
| 4  | [1188 – 1309]  | 1248.5| two    | 7       | 0.286 | one   | 80.59 |
| Total|             | 7    |         |         |        |        |       |

* K: Interval No.  
* Xi: Altitude interval  
* x'i: class mark  
* ni: absolute frequency  
* Ni: Accumulated absolute frequency  
* hi: relative frequency  
* Hi: Accumulated relative frequency

Figure 01. Behavior of stored carbon with respect to altitude.

Table 07 shows the frequency distribution, which indicates the altitude intervals (masl); In Figure 01, it can be seen that the behavior of the stored carbon with respect to altitude intervals, has its highest peak value in the interval from 1,066 to 1,187 masl.
Table 08. Data matrix for statistical analysis.

| altitude ranges | Category (Type of vegetation) | Carbon (tC/ha) | Carbon stored (tC/ha) |
|-----------------|-------------------------------|----------------|----------------------|
| [822 – 943]     | low pole                      | 0.68           | 28.19                |
|                 | tall pole                     | 1.67           |                      |
|                 | stems                         | 14.16          |                      |
|                 | mature trees                  | 11.68          |                      |
|                 | low pole                      | 0.79           |                      |
|                 | tall pole                     | 2.70           | 51.07                |
|                 | stems                         | 38.63          |                      |
|                 | mature trees                  | 8.96           |                      |
|                 | low pole                      | 3.34           |                      |
| [944 – 1065]    | tall pole                     | 4.39           | 170.85               |
|                 | stems                         | 14.35          |                      |
|                 | mature trees                  | 148.76         |                      |
|                 | low pole                      | 3.79           |                      |
| [1066 – 1187]   | tall pole                     | 6.02           | 80.59                |
|                 | stems                         | 43.86          |                      |
| [1188 – 1309]   | mature trees                  | 26.92          |                      |

Figure 02. Carbon behavior according to altitude intervals and vegetation type category.

Table 08 shows the matrix of tabulated data, which served as a basis to be able to work in the IBM SPSS Statistics Trial (Classic student) software. Figure 02 shows us the behavior of the altitude range and the categories of vegetation type with respect to stored carbon. It can be seen that the lines most similar to carbon are defined by mature trees and stems, and a slight influence by the high and low latizales.

Table 09. ANVA of interaction of altitude, category of vegetation type vs stored carbon.

| Variation Source | GL | SC     | CM     | F      | S.I.G.* |
|------------------|----|--------|--------|--------|---------|
| Altitude         | 3  | 5844.58| 1948.19| 18.19  | 0.00*   |
| Category         | 3  | 11872.77| 3957.59| 36.96  | 0.00*   |
| Altitude*Category| 9  | 22541.47| 2504.60| 23.39  | 0.00*   |
| Error            | 16 | 1713.04| 107.06 |        |         |
| Total            | 31 | 41971.87|        |        |         |

*: Significant
**: Not significant

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In Table 09, it indicates that at a significance level of 95% the amount of stored carbon is statistically influenced by altitude and vegetation type categories, and the interaction of these two variables evaluated in the field.

IV. DISCUSSION

Salvador (2014) carried out a study of the diversity of tree species in the Tres de Mayo sector of the PNTM, finding 16 families at different altitude levels, and abundance greater than 131 species with a total sampling of 294 species. Likewise, Valencia (2015) in the study carried out in the Tres de Mayo sector, 28 families and 52 forest species have been found; where at altitudes of 800 to 900 masl the cumala (Virola sebifera Aublet) and shimbillo (Inga altísima Mark) species predominate, from 900 to 1000 masl, the cumala (Virola sebifera Aublet) and cachimbo (Cariniana domestica Ducke) species, from 1000 to 1100 masl the ishanga species (Urera bacifera L. Gaudich) and black moena (Aniba perutilis Hemsley Kew), from 1100 to 1200 masl the chimicua species (Pseudo/medio Jaevis (Ruiz & Pavón)) and shimbillo (Inga altísima Mark), from 1200 to 1300 masl the yacushapana species (Terminalia oblonga (R. et. P) Eichler) and shimbillo (Inga altísima Mark), from 1300 to 1400 masl the guayabilla species (Rhiogspira quadrangularis (Muell. Arg.) Miers) and cumula (Virola sebifera Aublet), and at altitudes of 1,400 to 1,500 masl the species guayabilla (Rhiogspira quadrangularis (Muell. Arg.) Miers) and shimbillo (Inga altísima Mark); In contrast to the results obtained on absolute abundance, we identified 28 families, 73 tree species out of a total of 1837 individuals; the absence of some and the presence of other species is due to spatial distribution (physiography), species dispersion and site quality, among other factors. In contrast to the results obtained on absolute abundance, we identified 28 families, 73 tree species out of a total of 1837 individuals; the absence of some and the presence of other tree species is due to spatial distribution (physiography), species dispersion and site quality, among other factors.

Sosa (2016) states that forest biomass is currently an important element in studies on the changes that occur on a global scale, thanks to the attenuating effect (sink) that forests and related systems can have by sequestering excess greenhouse gases, greenhouse, temporarily (biomass) and permanently (soil). In the case of Tingo María National Park, it is an area protected by the state, which already plays an important role in the face of global problems and reduces and stores a large proportion of CO2 from the atmosphere. Manta (1988) indicates that a forest is out of risk and management can be carried out if there are at least 150 individuals per hectare with a DBH between 10 and 40 cm, a category corresponding to stems, therefore.

Güere (2015) in the study carried out in the Tingo María National Park, indicates that the stored carbon found is influenced by 56.73% specifically by mature trees with more than 40cm in diameter at breast height, followed by 29.9% in the stems. Joining both categories exceed ¾ parts of the total stored carbon found; the results obtained in the present investigation indicate that mature trees store 50% of the carbon per hectare, followed by poles with 42%, tall poles with 5% and low poles with 3%. These results allow the potential to become sources of CO2 emissions; therefore, it is an area protected by the state, which already plays an important role in the face of global problems and reduces and stores a large proportion of CO2 from the atmosphere. Manta (1988) indicates that a forest is out of risk and management can be carried out if there are at least 150 individuals per hectare with a DBH between 10 and 40 cm, a category corresponding to stems, therefore.

IDEAM (2010) indicates that the content of biomass and carbon potentially stored in the forests of the National Natural Parks system of Colombia, specifically for tropical humid forests, the average carbon value for this type of natural forest is 130.44 t/ha, compared with the results obtained of 70.08 tC/ha can be considered representative, if it is taken into account that the study only worked on the tree aerial biomass, and not the other carbon storage components of an area. It is important to bear in mind that, due to the significant carbon content of these primary forests, they also have a high potential to become sources of CO2 emissions; therefore, surveillance control must be taken into account so that the surrounding population does not affect the natural forest.

Gonzales (2013) mentions that criteria such as type of forest or vegetation, density of wood, adjustment factors based on biomass data calculated from volumes per hectare of forest inventories, as well as conditions are taken into account. Of the site, such as location and climate. Cubero and Rojas (1999), point out that the carbon content in tree biomass is influenced by the quality of the site and age of the plantations, the results obtained indicate that mature trees (older) and stems are the ones that stored the greatest the carbon in the biomass, and also to other factors mentioned by previous authors that are the density, years of life, altitude,
climate conditions and quality of the site where they develop. Cuellar and Salazar (2016) in a study carried out on the dynamics of stored carbon indicate that the warm and rainy climate of humid tropical forests generates rapid plant growth and most of the carbon is found in the vegetation. Carbon stocks, as in the case of the PNTM with a humid tropical forest, vary considerably depending on the abundance of trees and factors that affect their growth.

V. CONCLUSIONS

The carbon in the living tree aerial biomass of the wild area of the Tingo María National Park was on average 70.08 tC/ha. The carbon in the living tree aerial biomass of the wild area of the Tingo María National Park, according to the categories of vegetation type, was 50% (49.08 tC/ha) for mature trees, 42% (27.75 tC/ha) for poles, 5% (3.82 tC/ha) for tall poles and 3% (2.15 tC/ha) for low poles.

VI. REFERENCES

[1] Allen, W. (2001). Statistics applied to business and economy. Trad. by Yelka García. 3ed. Bogota, Colombia, McGraw-Hill. 543p.

[2] Borrero, J. (2012). Aerial biomass and carbon content in the campus of the Pontificia Universidad Javeriana in Bogotá. Thesis for Ecologist Degree. Bogota Colombia. Pontificia Javeriana University. 54p.

[3] Chave J, Andalo S, Brown A, Cairns J, Chambers H, Folster F, Fromard N, Higuchi T, Kira J, Lescure B, Nelson H, Ogawa H, Puig B, Riera Y, Yamakura. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: 87-99

[4] Cubero, JY, Rojas, R. (1999). Carbon fixation in plantations of Gmelina arborea, Tectona grandis and Bombacopsis quinata in the cantons of Hojancha and Nicoya. Thesis (Bachelor's Degree in Forest Sciences). National University. Guanacaste, Costa Rica. 93 pages

[5] Cuellar, J., Salazar, E. (2016). Dynamics of carbon stored in the different systems of land use in Peru. Lima Peru. National Institute of Agrarian Innovation INIA. 217 pages

[6] Dominguez, E. (2010). Instruments for measuring dasometric variables. Foundations and elaboration with the student of the training cycle "Higher Technician in Management and Organization of Landscape Natural Resources". Innovation and Educational Experiences. Innovation and Educational Experiences. Cordoba, Argentina, 9 p.m.

[7] Gonzales, P. (2013). Economic assessment of CO2 sequestration in plantations of Vochysia lomatophylla (standl) "quillosisa" of different ages at CIEFOR Puerto Almendro. Thesis (Tropical Forest Ecology Engineer). National University of the Peruvian Amazon. Faculty of Forest Sciences. Iquitos-Peru. 74 p.

[8] Guere, F. (2015). Carbon stored in the protected forest area of the Tingo María National Park. Thesis Mg. Sc. In Agroecology Mention in Environmental Management. Tingo Maria, Peru. Postgraduate School of the National Agrarian University of La Selva. 109 pages.

[9] IDEAM. (2010). Executive summary of the technical report on the estimation of the potential reserves of carbon stored in the aerial biomass in the natural forests of Colombia, Institute of Hydrology, Meteorology and Environmental Studies of Colombia. Bogota DC (Colombia). 42p.

[10] IPCC. (2001). The Carbon Sinks. Retrieved from www.cescy1.es/pdf/coleccionestudios/Pkioti.pdf.

[11] IPCC. (2003). Integrated pollution control and prevention. Retrieved from http://eippcb.jrc.ec.europa.eu/reference/BREF/ivo_bref_0203.pdf.

[12] IPCC. (2018). Impacts of 1.5°C Global warming on natural and human systems. IPCC special report. Recovered from https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf.

[13] Lamprecht, H. (1990). Forestry in the Tropics: Forest ecosystems in tropical forests and their tree species; possibilities and methods for sustained use. (Deutsche Gesellschaft für Technische Zusammenarbeit) GTZ. German Federal Republic, Germany. 335p.

[14] Blanket, M. (1988). Silvicultural analysis of two types of humid lowland forest on the Atlantic slope of Costa Rica. Thesis. mg. SC. Turrialba, Costa Rica. CATIE. 137 pages

[15] Morels, A. (2007). Sampling in finite populations. Retrieved from http://webpersonal.uma.es/~morillas/muestreo.pdf.

[16] Murray, R., Jacobson, M. (1982). An evaluation of dimension analysis for predicting shrub biomass. Journal of Range Management 35:451–454.

[17] Ortiz, M. (1993). Techniques for estimating the growth and yield of individual trees and forests. Carthage, Costa Rica. Technological Institute of Costa Rica. 71 p.

[18] Pinelo, G. (2000). Manual for the establishment of permanent sampling plots in the Maya Biosphere.
Reserve, Peten, Guatemala. Turrialba, Costa Rica. Tropical Agronomic Center for Research and Teaching. 68p.

[19] Salvador, A. (2014). Diversity of tree species (decits/individual) as an indicator of environmental quality at the different levels of the Tingo Maria National Park. Pre-professional practice. Tingo Maria, Peru. Academic Department of Environmental Sciences. 71p.

[20] Sosa, J. (2016). Economic valuation of CO2 sequestration in three types of forest in the District of Alto Nanay, Loreto - Peru - 2014. Thesis for Forestry Engineer. Iquitos, Peru. School of Forestry Engineering of the National University of the Peruvian Amazon. 99p.

[21] Valencia, R. (2015). Diversity of forest species in the wild area of the Tres de Mayo sector of the Tingo Maria National Park. Thesis for RNR Forestry Mention Engineer. Tingo Maria, Peru. Faculty of RNR of the National Agrarian University of La Selva. 140p.

[22] Vallejo, M., Londoño A., López R., Galeano G., Álvarez E., Devia W. (2005). Establishment of permanent plots in forests of Colombia. Bogota DC, Colombia. Alexander von Humboldt Biological Resources Research Institute. 310 p.

[23] Vargas, V. (2007). Descriptive Statistics for Environmental Engineering with SPSS. Cali, Colombia. FERIVA SA 312p printer.

[24] Wieman, M., Williamson, G. (1989). Wood specific gravity gradients in tropical dry and montane rain forest trees, American Journal of Botany 76 (6): 924-928.