REVISTA FLORESTA
Engenharia Florestal
ISSN 1982-4688
Edição 54
Universidade Federal do Paraná
Setor de Ciências Agrárias

BIOMASS, STORED CARBON, AND CO_2 REMOVED IN A *Humiriastrum procerum* LITTLE FOREST IN CHOCÓ, COLOMBIA

Yessika Biasney Serna Mosquera[1*], Rosalina Gonzalez Forero[2]

[1*]Universidad Tecnológica del Chocó, Programa de Ingeniería Agroforestal, Quibdó, Chocó, Colombia - d-yessika.serna@utch.edu.co
[2]Universidad de La Salle, Doctorado en Agrociencias y Programa de Ingeniería Ambiental y Sanitaria, Bogotá, Distrito Capital, Colombia – rogonzalez@unisalle.edu.co

Received for publication: 14/01/2024 – Accepted for publication: 04/06/2024

Resumo

Biomassa, carbono armazenado e co₂ removidos em uma pequena floresta de Humiriastrum procerum em Chocó, Colômbia. A biomassa da colheita florestal é um material proveniente de procedimentos silviculturais que pode ser quantificado, manejado e utilizado. Este estudo teve como objetivo avaliar a biomassa, o carbono armazenado e o CO_2 removido por *Humiriastrum procerum* através de sua utilização em San Francisco de Ichó, em Quibdó, Chocó. Para o efeito foi estabelecida uma área de exploração de 2 Ha com 10 subparcelas de 40 x 50m. A biomassa, o carbono armazenado e o CO_2 removido foram calculados a partir do material colhido. A biomassa dos blocos gerou 10,73 t ha^{-1} e 27,38 t ha^{-1} de resíduos. O carbono em blocos gerou 5,36 t ha^{-1} e 13,79 t ha^{-1} em resíduos, enquanto o CO_2 removido em blocos gerou 19,62 t ha^{-1} e 50,11 t ha^{-1} em resíduos. A presença de *Humiriastrum procerum* no ecossistema evidencia elevado volume de biomassa e carbono nos produtos obtidos (blocos), bem como em resíduos de galhos, sobras e pequenos galhos. Também retirou elevadas quantidades de CO_2, mitigando assim as alterações climáticas, o que deverá ser de interesse para a sua gestão e conservação.
Palavras-chave: resíduos florestais, volume comercial, carbono armazenado, colheita florestal.

Abstract

Forest harvest biomass is a material originating from silvicultural procedures that can be quantified, managed, and utilized. This study aimed to evaluate the biomass, stored carbon, and CO_2 removed by *Humiriastrum procerum* through its utilization in San Francisco de Ichó, in Quibdó, Chocó. For this purpose, a 2 Ha exploitation area with 10 subplots of 40 x 50m was established. The biomass, stored carbon, and CO_2 removed were calculated from the harvested material. Biomass for blocks generated 10.73 t ha^{-1}, and 27.38 t ha^{-1} in residues. Carbon in blocks generated 5.36 t ha^{-1}, and 13.79 t ha^{-1} in residues, while CO_2 removed in blocks generated 19.62 t ha^{-1} and 50.11 t ha^{-1} in residues. The presence of *Humiriastrum procerum* in the ecosystem shows a high volume of biomass and carbon in the products obtained (blocks), as well as in branch residues, offcuts, and small branches. It also removed high amounts of CO_2, thus mitigating climate change, which should be of interest for its management and conservation.
Keywords: forest residues, commercial volume, stored carbon, forest harvesting.

INTRODUCTION

H. procerum is a timber species of the Humiriaceae family that generally grows in premontane humid forests and tropical humid forests in Colombia. It is one of the most exploited species for its wood from natural forests in Colombia, highly demanded in the market; its demand value is one of the highest at U$203.21 per m^3, and its compensatory rate (a tax paid for its forest exploitation to the environmental entity that grants the exploitation permit in a region) is also one of the highest at U$13.37 per m^3 in the very special species category. Particularly in Chocó in 2022, 48,293.58 m^3 of wood of this species were moved. (Regionally, its wood is used for the construction of tables, doors, and general construction (houses, boats, and household implements) (TORRES *et al*. 2019), being a highly exploited and very valuable species, for which specific assessments are imperative to guide its management and planning.

Accurate estimation of commercial volume and wood biomass is key data for efficiently implementing forest exploitation regulations determined by forestry institutions and ensuring the sustainable management of forest resources in various mitigation environments to conserve forests (BORGES *et al.* 2021). Similarly, estimating the biomass and carbon generated and/or accumulated by forest blocks is necessary to measure the forest services they provide to the communities that inhabit them and to generate regulations for their use in various local economic activities that depend on such activities. (RODRIGUEZ, 2013).

In Colombia, and particularly in Chocó, no specific regulations are known for the exploitation of volumes and biomass of tree felling residue from harvesting forests subject to exploitation (SERNA; GONZÁLEZ, 2022). While the Chocó Regional Autonomous Corporation, Codechocó has created forest management plans (CODECHOCÓ, 2016), they are outdated. The responsibility for the exploitation and management of the volume and biomass falls to the applicant for the exploitation permit, and therefore, the management plan presented is often not executed. Currently, markets for harvest residues are strongly developing (HARVEY; VISSIER, 2022), so their estimates are a necessity. Accurate and reliable estimates of these variables are required in these forests to define both the maximum exploitable wood volume that allows calculating revenues and the long-term functioning of the forest since they play an important role in CO_2 fixation, regulating the carbon exchange between the atmosphere and forest ecosystems.

In this context, it is worth mentioning that the highest CO_2 concentrations in America are found in very wet and humid tropical forests with 135.29 t ha^{-1} and 131.87 t ha^{-1}, respectively (IBARGUEN *et al*. 2023). Regionally, the Pacific ranks second, after the Amazon, with the highest average carbon levels (131 t ha^{-1}), even though its total area is one of the smallest (7 million hectares) (RÍOS; TRIANA, 2018), hence the importance of carrying out continuous monitoring through its study. Therefore, this study aimed to evaluate the biomass, stored carbon, and removed carbon by the *Humiriastrum procerum* little species, in the typically exploited component (blocks) and residue components (branches, cuttings, leaves, and stumps) from the forest harvest of this species.

MATERIALS AND METHODS

Study Area

This research took place in the San Francisco de Ichó district, in the municipality of Quibdó, Chocó, Colombia. The community is located at 5°46' north latitude and 76°30' west longitude in the western part of the country, in a tropical rainforest zone (bp-T) with an average temperature of 26°C and precipitation exceeding 7,000 mm annually (RANGEL; ORELLANO, 2004). It has an agricultural, livestock, mining, and forestry-based economic system, with forestry activities as a strong forerunner in the economy through the commercialization of wood.

Sampling

A space was demarcated according to a cutting area of the timber exploitation activities that had an extraction permit in January 2022. Following TORRES *et al.* (2019), an area of 2 ha (40 m x 500 m) was selected, which contained species of socio-economic interest with a diameter ≥ 40 cm. Within this unit, 10 subplots of 40 m x 50 m (0.2 ha, Figure 1) were set up, where data from the selected species harvest were evaluated.

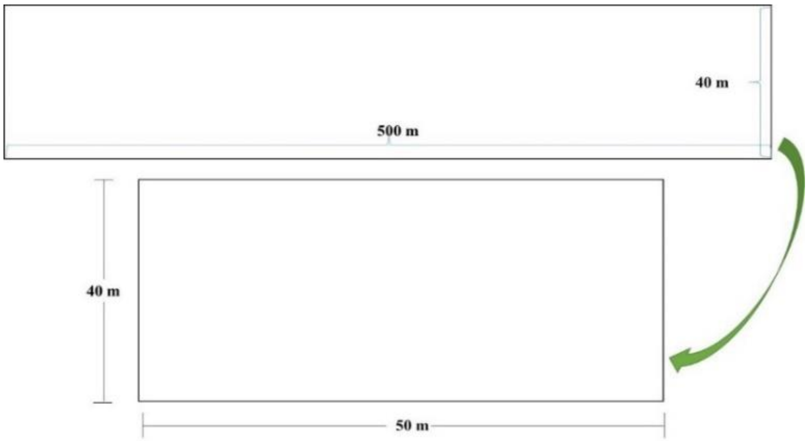

Figure 1. Scheme of subplots used to collect field information.
Figura 1. Esquema de subparcelas usadas para coletar informações de campo.

Records and Measurement Variables

A field notebook was created to record tree number, plot number, common name, diameter at breast height (DBH), total and commercial height, and the presence of lianas, as indicated in JIMÉNEZ *et al.* (2020). Additionally, general data such as date, responsible person, and site information were included. For volume calculation, variables such as basal area and height and a morphic factor for the zone were used. For basal area, DBH and a constant of 0.7854, resulting from the quotient of π/4, were used.

Tree Felling and Branch Removal.

The trees were felled with a chainsaw (STIHL MS382) above the stump at a height of 0.30m upwards on the trunk.

Volume Estimation for the Trunk and Residue Components.

Records of trunk components (blocks) and residues (leaves, branches, stumps, cuts) were obtained for volume, biomass, and captured carbon measurement in 20 individuals (a representative number for this type of species in these very heterogeneous forests), from which residues were extracted during the harvest using expressions given by Smalian and replicated by other authors, as expressed in Table 1.

Table 1. Calculation expressions for products and residue components in the forest harvest of *H. procerum.*
Tabela 1. Expressões de cálculo dos produtos e componentes dos resíduos da colheita florestal de *H. procerum*.

Products	Ecuations	Conventions
Wooden blocks	$V = L * A * E$	*V*= Block volume (m3) *l*= Block length (m) *TO*= Block width (m) *AND*= Block thickness (m) (TORRES *et al*., 2019)
Thick branches	$V = 0.7854\left(\frac{D+d}{2}\right)^2 * L$	V= Volume of the branch (m3) D= Largest diameter of the branch (m). d= Smallest diameter of the branch (m) 0.7854= Constant of the quotient of $\pi/4$ L= branch length (m) (Smalian).
Stumps	$V = L\left(\frac{Di+Do}{2}\right)^2$	V= Stump Volume (m^3) L= Stump Length (m) D_i= Diameter of the upper section (m^2) D_0= Diameter of the section at ground level (m^2)
Corner pieces	$V_{cantonera} = VT - VB$	*V coastal*: Volume of the coastal pieces (m^3) *V.T.*: Log volume (m^3) *V.B.*: Block volume (m^3). (Smalian).
Small branches	$V = \pi/4\frac{(d_1 + d_2)2}{2} * L$	Vbranch= Volume (m^3) d = Diameter in the middle of the branch (m) L= length (m)
Leaf biomass (leaves (+fruits+liana))	$BH = PFH\ x\ promedio \frac{Psm\ (kg)}{Pfm\ (kg)}$	*B.H.*: leaf biomass (kg). *PFH*: total fresh weight of leaves. *Average*: average of three leaf subsamples (kg). *Psm*= dry weight of the leaf subsample (kg). *Pfm*= fresh weight of the leaf subsample (kg). (LÓPEZ *et al*. 2018)

Specific Density.

For three *H. procerum* trees, three slices of approximately 5 cm in thickness were taken from different sections: immediately above the stump, at normal diameter height (1.30 cm), and below where the first branch starts, to be processed in the laboratory to obtain the basic density of the species. For processing the subsamples, three irregular samples of 3 cm thickness x 3 cm height x 15 cm length were obtained in the three sections; the initial fresh weight and initial fresh or green volume by water displacement (Archimedes' Principle) in a 500 ml hexagonal plastic graduated beaker (Brixco), of high-strength polypropylene, were obtained and recorded, ensuring the wooden samples were held with a clamp at the transverse end, preventing them from touching the beaker's sides and bottom (LÓPEZ *et al.* 2018). Subsequently, the samples were dried in an oven at 102°C ± 3 for approximately 72 hours until stabilized, cooled in a desiccator, and their dry weight recorded. The specific or basic density of the lower, middle, and upper trunk sections was then obtained with the following expression, relating the mass and the green volume (LÓPEZ *et al.* 2018):

$$DE = \frac{Peso\ secado\ al\ horno\ sección\ (g)}{Volumen\ fresco\ sección\ (cc)}$$

Biomass of the Trunk and Residue Components.

To estimate the biomass of the trunk and residues (branches, stumps, cuts, and leaves), the average volumes calculated for these were used, as well as the basic density of the species, adjusted to the estimates made by INECC (2013) with the following equation:

$$B = V * Db$$

Where: *B* = Biomass component (kg), *V* = Sample volume (m^3), *Db* = Basic density (kg/m^3).

Carbon Content in the Aerial Biomass of the Trunk and Residue Components.

For carbon estimation, the calculated aerial biomass was multiplied by the fraction of 0.5, as suggested by QUICENO *et al.* (2016) and MENA *et al.* (2022), using the following expression:

$$CA = BT * 0.5$$

Where: CA = Stored carbon content (kg), BT: Total or component biomass (kg), 0.5: Carbon fraction (0.5)

Estimation of CO_2 removed from the atmosphere by the species.

Once the stored carbon values were obtained, the amount of sequestered CO_2 in the components was calculated by multiplying the carbon stocks by 3.66, which is the result of the molecular weight ratio of CO_2 to carbon 44/12 (IPCC, 2016), and PÉREZ and BONILLA (2015).
Constant: 3.66. For every kg of Carbon found in the tree biomass, it has captured 3.66 kg of CO_2.

Data Analysis

Field and laboratory information was recorded in Excel tables, documenting the names of species present in the inventory along with the species of interest. For the species of interest, DBH was recorded using calipers and respective heights to determine the basal area and total trunk volume with bark using volume equations (MENA et al., *2022)*. Subsequently, the volume of the components was calculated, followed by the calculation of the above-ground biomass of each component using this volume and the basic density obtained for the species. Additionally, with this biomass and the 0.5 fraction *(*MENA *et al*., 2022), the stored carbon was calculated for the trunk and for each residue component generated in the forest harvest of the species; and the CO_2 removed from the atmosphere was determined as well.

RESULTS

Economically important species accompanying the chanó species in the studied area.

In the studied site, 12 botanical species of the highest current commercial value were recorded, grouped into 10 families (Table 2). These species in the forest are accompanied by yarumos (*Cecropia* spp.), pacó (*Gustavia excelsa* R. Knuth), güina (*Carapa guianensis* Aubl.), cedar (*Cedrela odorata* L.), among other species which, for various reasons such as depletion or wood quality, do not have significant economic importance in the local and national market (TORRES *et al*. 2019).

Table 2. Species of current economic importance, found at the sampling site.
Tabela 2. Espécies de importância econômica atual, encontradas no local de amostragem.

No.	Family	Gender	Species	Common name
1	Apocynaceae	*Couma*	*Couma macrocarpa* Barb. Rodr.	Lily
2	Burseraceae	*Protium*	*Protium amplum* Quadrec.	Anime
3	Fabaceae	*Inga*	*Inga acrocephala* Steud.	Guamillo
		Piptadenia	*Piptadenia*sp	Yellow pine
4	Humiriaceae	*Humiriastrum*	*Humiriastrum procerum* (Little) Cuatrec.	Chano (registration # 18234,18235,18236. Herbarium Technological University of Choco)
5	Lecythidaceae	*Couratari*	*Couratari stellata*	Guasca Peo
		Eschweilera	*Eschweilera integrifolia* Mart.	Guasca
6	Moraceae	*Brosimum*	*Brosimum utile* (Kunth) Oken	Dairy
7	Myristicaceae	*Otoba*	*Otoba latialata* (Pitt.) AH Gentry	Nuanamo
8	Olacaceae	*Minquartia*	*Minquartia guianensis*	Truntago
9	Rubiaceae	*Psychotria*	*Psychotria* sp.	Boteco
10	*Sapotaceae*	*Manilkara*	*Manilkara* sp.	Medlar

REVISTA FLORESTA Engenharia Florestal
ISSN 1982-4688
Edição 54
Universidade Federal do Paraná
Setor de Ciências Agrárias

Characteristics of *H. procerum* associated with the forest exploitation area.

Table 3 shows the dendrometric and volumetric characteristics of *H. procerum* recorded at the study site in 2 hectares (reported per 1 ha, based on the premise that natural forests in the region are highly heterogeneous, hence a high number of the same valuable species individuals are not found in small areas and any observed valuable individual is subject to exploitation). The average DBH was 51 cm, the average total height was 24.6 m, the average commercial height was 19.95 m, the average sub-plot volume was 3.78 m^3, the average individual volume was 1.89 m^3, and the total trunk volume was 37.82 m^3/ha.

Table 3. Structural characteristics of H. procerum individuals in the study area.
Tabela 3. Características estruturais dos indivíduos de H. procerum na área de estudo.

Subplot	Tree No.	Species (Regional name)	DBH (cm)	Total height (m)	Commercial height (m)	Basal area (m^2)	Volume (m^3/2ha)	Volume (m^3/ha)
1	1	Chano	55	28	22	0.238	4.657	2.328
1	2	Chano	fifty	26	21	0.196	3.574	1.787
2	3	Chano	Four. Five	28	22	0.159	3.117	1.559
2	4	Chano	48	22	18	0.181	2.787	1.393
3	5	Chano	60	26	18	0.283	5.146	2.573
3	6	Chano	49	26	20	0.189	3.432	1.716
4	7	Chano	55	26	20	0.238	4.324	2.162
4	8	Chano	42	19	19	0.139	1.843	0.921
5	9	Chano	64	28	22	0.322	6.305	3.153
5	10	Chano	47	22	17	0.173	2.672	1.336
6	11	Chano	65	28	22	0.332	6.504	3.252
6	12	Chano	43	24	18	0.145	2.440	1.220
6	13	Chano	48	22	18	0.181	2.787	1.393
7	14	Chano	48	26	20	0.181	3.293	1.647
7	15	Chano	56	26	20	0.246	4.483	2.241
8	16	Chano	47	24	18	0.173	2.915	1.457
8	17	Chano	68	28	24	0.363	7.118	3.559
8	18	Chano	41	22	18	0.132	2.033	1.017
9	19	Chano	43	26	20	0.145	2.643	1.322
10	20	Chano	15	26	22	0.196	3.574	1.787
	Total					4.212	75.645	37.822
	Average		51	24.6	19.95	---	---	1.89

Biomass of the usable component (blocks) and residue components.

The biomass of the usable component (blocks) was 10.73 t ha^{-1} and the residue components presented 27.38 t ha^{-1}; this biomass was distributed in branch residues with 16.93 t ha^{-1}, cuts with 10.059 t ha^{-1}, twigs with 0.32 t ha^{-1}, foliage (leaves) with 0.039 t ha^{-1}, and stumps with 0.033 t ha^{-1}; the total biomass for the species was 38.11 t ha^{-1} (Table 4). These values in percentage correspond to 28% in commonly used wood (blocks), 44% in branches, 26% in cuttings, 0.84% in twigs, 0.09% in stumps, and 0.10% in leaves (Figure 2).

REVISTA FLORESTA Engenharia Florestal
ISSN 1982-4688
Edição 54
Universidade Federal do Paraná
Setor de Ciências Agrárias

Table 4. Biomass of usable components and residues in the forest harvest of *H. procerum*.
Tabela 4. Biomassa de componentes aproveitáveis e resíduos na colheita florestal de *H. procerum*.

Tree component	**Biomass (t ha^{-1})**
Usable component	
Blocks	10.73
Waste component	
Corner pieces	10,059
Foliage (leaves)	0.039
Branches	16.93
Small branches	0.32
Stump	0.033
Total species residue	27.382
Total species biomass	38.11

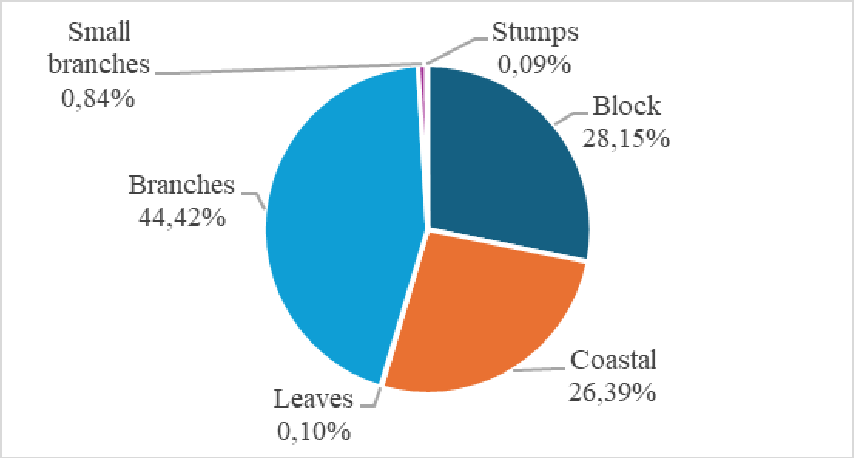

Figure 2. Biomass in % of woody components for 1 ha, in the use of *H. procerum*.
Figura 2. Biomassa em % de componentes lenhosos por 1 ha, no uso de *H. procerum*.

Carbon content in the biomass of the usable component and residues in the harvest of *chanó*.

The carbon content of the commonly utilized component (blocks) was 5.36 t ha^{-1} and the residue components were 13.69 t ha^{-1}. The total carbon of the residue components was distributed in branches with 8.47 t ha^{-1}, cuts with 5.03 t ha^{-1}, small branches with 0.16 t ha^{-1}, foliage (leaves) with 0.019 t ha^{-1}, and stumps with 0.017 t ha^{-1}. The total carbon for the species was 19.05 t ha^{-1} (Table 5).

Table 5. Carbon content of the usable trunk (blocks) and residues of *H. procerum*.
Tabela 5. Conteúdo de carbono do caule utilizável (blocos) e resíduos de *H. procerum*.

Tree components	**Stored carbon (t ha^{-1})**
Blocks	5.36
Corner pieces	5.03
Foliage (leaves)	0.019
Branches	8.47
small branches	0.32
Stump	0.016
Total species residue	13.69
Total species biomass	19.05

CO_2 removal from the atmosphere in the usable component and residue components of *H. procerum*.

The total CO_2 removal by the species *H. procerum* in the Pundú ecosystem in the district of San Francisco de Ichó, in Quibdó, was 69.72 t ha^{-1}, of which 50.11 t ha^{-1} corresponds to the residual components such as branches, offcuts, leaves, and stumps, and 19.62 t ha^{-1} correspond to the usable component or wood blocks (Table 6).

Table 6. CO_2 removal from the atmosphere in the usable component and residues by *H. procerum*.
Tabela 6. Remoção de CO_2 da atmosfera em componentes utilizáveis e residuais por *H. procerum*.

Tree components	Carbon retention in components (t ha^{-1})	CO_2 removal (t ha^{-1})
Wooden blocks	5.36	19.62
Corner pieces	5.03	18.41
Foliage (leaves)	0.019	0.070
Stump	0.017	0.062
Branches	8.47	31.00
Small branches	0.16	0.59
Total waste	13.69	50.11
Total species	19.05	69.72

DISCUSSIONS

Biomass of the usable component (blocks) and residue components.

The biomass of H. procerum in this study showed high values (38.11 t ha-1) compared to those reported by SÁNCHEZ *et al*. (2020) in Mulukuku, Nicaragua, which found 11.63 t ha^{-1} in nancitón (*Hyeronima alchorneoides*), 11.63 t ha^{-1} in roble macuelizo (*Tabebuia rosea*), and for various other species was 24.28 t ha^{-1}; the biomass of chanó was only lower than that of chinche (*Zanthoxylum fagara*) *at* 40.19 t ha^{-1}. Similarly, RODRÍGUEZ *et al*. (2016) reported 95.21 t ha^{-1} for *Qualea paraensis, Cedrelinga cateniformis,* and *Couma* spp., adding up the three species.

Upon observing the biomass of chanó with previous studies, it could be indicated that these conditions may be due, among other factors, to *H. procerum* being a dominant species of the upper canopy in forests, presenting large and wide crowns that can contribute to capturing favorable climatic conditions for collecting environmental elements that favor their development processes in the forest. Additionally, according to field observations, it is a species that manages to expand at the development site, not allowing the growth of other species nearby, forming almost pure stands (IUCN, 2019), although sometimes it is found associated with sande (*Brosimum* spp.) and cuánguare (*Virola* spp.) species. Furthermore, the evaluated individuals are pole-sized trees, i.e., adults ≥ 40, and the accumulated biomass increases with age (TORRES *et al*., 2017).

Carbon content in the above-ground biomass of the usable component and residue components in the harvest of *H. procerum.*

The stored carbon in the biomass of usable components (blocks) was 5.36 t ha^{-1} and for residual components 13.69 t ha^{-1}; the total for the species was 19.05 t ha^{-1}, higher than reported by SÁNCHEZ *et al*. (2020) for forests in Nicaragua, which recorded stored carbon in their study for the chinche species (*Z. fagara*) at 10.95 t ha^{-1}, nancitón (*H. alchorneoides*) 5.83 t ha^{-1}, roble macuelizo (*T. rosea*) 5.81 t ha^{-1}, and other species at 12.14 t ha^{-1}. Similarly, TORRES *et al.* (2017) reported in a forest area in the Pacific (Bahía Solano) carbon for three ages (three types of forest: 12, 30, and 40 years as seedlings, saplings, and pole-sized trees) with an average stored carbon of 48.2 t C ha^{-1}; the trunk forests (40 years) in their study had the highest carbon content with 68.1 t C ha^{-1} for the vegetation of the entire ecosystem, showing similarity with this study regarding pole-sized trees with DBH ≥ 40 cm. On the other hand, MENA *et al*. (2022) recorded average carbon for a complete ecosystem of more than 1678 individuals, storing 29.5 t ha^{-1}.

BÁMACA *et al*. (2004) in Costa Rica recorded a total carbon extraction of 5.48 t ha^{-1} and carbon for branch residues of 2.46 t ha^{-1}, with minor importance generated in twigs, non-commercial pole-sized trees, and stumps; both studies were below the carbon record of *H. procerum,* which also in the branch residue component was 8.47 t ha^{-1}, showing differentiation in the records. In this context, FONAM (2005), LEUSCHNER *et al*. (2007), and YEPES *et al*. (2011), cited in TORRES *et al*. (2017, p. 7), state that the significant differences in biomass and carbon content from one location to another are due to the systemic increase of physiological limitations imposed by woody plants. Factors such as temperature, slope gradient, cloud cover, and the availability of soil nutrients where the trees are located significantly influence these variations.

Removal of CO_2 from the atmosphere in the harvestable component and residual components of chanó.

According to this evaluation, the species *H. procerum* in the natural ecosystem of San Francisco de Ichó, Quibdó, in the Colombian Pacific, stores an average of 19.05 t ha^{-1} of carbon, almost half of what TORRES *et al*. (2017) reported for natural forests in the Pacific (48.2 t ha^{-1}) stored in the aerial biomass in three categories: seedlings, saplings, and pole-sized trees over 96.3 ha of the Pacific Botanical Garden in Bahía Solano for various species, reaching *H. procerum* at 39.5% compared to that report and 74.4% compared to MENA *et al*. (2022) in ecosystems of Bajo Baudó. This is possibly because the evaluated individuals of *H. procerum* in the Ichó ecosystem were mostly adults, and biomass, and therefore stored carbon, increases with the growth of individuals. Additionally, this species is dominant with wide canopies in the upper canopy, favoring its growth and forming almost pure ecosystems (IUCN, 2019). Nevertheless, the amount of biomass and stored carbon by this species is noteworthy, highlighting the importance of implementing management plans for its conservation, as the other studies record the entire ecosystem (PALACIOS *et al*., 2017). Furthermore, it is worth evaluating other characteristics in future studies, such as soil type, topography, among others.

Additionally, the biomass and carbon stored in the species (19.05 t ha^{-1}) is a high figure compared to the approximately 190 t ha^{-1} of carbon stored in the forest vegetation of Tropical America according to Brown *et al*. (1996) for this type of vegetation, where the carbon stored by this species would represent 10.02% of the accumulated carbon according to this comparison.

On the other hand, the removal of CO_2 corresponds to 69.72 t ha^{-1}, of which 19.62 t ha^{-1} (Table 7) are 28% removed in the components usually used as wood blocks and about 50.11 t ha^{-1} in waste components such as branches, cuttings, stumps, and foliage (leaves), which corresponds to 72%. The local industry wastes 72% in residues that remove more CO_2 from the atmosphere in the ecosystem since these are inadequately disposed of and later deposited in watercourses in large amounts of waste, contributing to the increase of other forms of carbon emissions into the atmosphere, which need to be avoided, considering that CO_2 in the atmosphere is responsible for 64% of global warming (UNITED NATIONS, 2023).

As a result, with 72% of waste discarded and carried away, local watercourses are polluted by the drift of timber (ESCOBAR *et al*., 2019) due to local precipitation (about 11,394 mm/year according to RANGEL; ORELLANO, 2004), and can contribute to high amounts of dissolved organic carbon in the sources.

CONCLUSIONS

- The forest harvest of chanó in Quibdó generates a large amount of waste since it is a forest that does not have any management throughout its growth and development.
- The harvesting operations generated 72% waste in its components compared to the products that are used which are only 28%.
- The *H. procerum* represents a significant reservoir as a carbon sink in the Ichó ecosystem in Quibdó; its biomass represents about 38.11 t ha^{-1} and captures an average of 19.05 t ha^{-1}.
- The harvest residues removed an average of 50.11 t ha^{-1} of CO_2 from the atmosphere compared to 19.62 t $há^{-1}$ from the product componente, indicating that the managing harvest residues is important as in regional plans.

ACKNOWLEDGMENTS

The authors especially thank the Universidad Tecnológica del Chocó "Diego Luis Córdoba" and the Madera (Wood) Project for funding the main author's doctoral studies.

REFERENCES

BÁMACA, E. E.; KANNINEN, M.; LOUMAN, B.; PEDRONI, L.; GÓMEZ M. Contenido del carbono en los productos y residuos forestales generados por el aprovechamiento y el aserrío en la Reserva de Biosfera Maya. **Recursos Naturales y Ambiente**. Bogor, p. 102 – 110, 2004

BORGES, R.; RUTISHAUSER, E.; ALEIXO, J. A.; CARNEIRO G. M.; HERAULT, B.; PEREIRA, C.; PERSEU, A.; DOFF, S. E.; SILVA, D. A.; RINALDO, R. L. Accurate Estimation of Commercial Volume in Tropical Forests. **Forest Science**. Oxford, v. 67, n. 1, p. 14 – 21, febrero de 2021.

BROWN, S.; SATHAYE, J.; CANNELL, M.; KAUPPI, P. E. Mitigation of carbon emissions to the atmosphere by forest management. **The Commonwealth Forestry Review**, v. 75, n. 1, p. 80 – 91, enero de1996.

ESCOBAR J. D.; CAÑÓN, J. E.; AGUILAR, Y.; ASPRILLA, D. B.; MATURANA J. C. Análisis del aprovechamiento sustentable de los residuos de la transformación de madera en dos municipios del Chocó (Colombia). **Ingeniería y Desarrollo**. Barranquilla, v. 37, n. 1, p. 192 - 211, 2019.

HARVEY, C.; VISSER, R. Characterisation of harvest residues on New Zealand's steepland plantation cutovers. **Zealand Journal of Forestry Science**. Rotorua, v. 52, n. 7, 2022.

IBARGUEN, Y. J.; MENA, V. E.; PINO, W. A. Determinación de fracción de carbono de especies forestales de tres bosques del departamento del Chocó, Colombia. **Colombia Forestal**. Bogotá, v. 26, n. 1, p. 22 .35, 2023.

INSTITUTO NACIONAL DE ECOLOGÍA Y CAMBIO CLIMÁTICO - INECC**. Inventario nacional de emisiones de gases de efecto invernadero 1990-2010**. México: Secretaría de Medio Ambiente y Recursos Naturales. 2013, 412 p.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE - IPCC. Metodologías genéricas aplicables a múltiples categorías de uso de la tierra. IPCC. Ginebra, V. 4, 2006, 66 p. https://www.ipcc-nggip.iges.or.jp/public/2006gl/spanish/pdf/4_Volume4/V4_02_Ch2_Generic.pdf

JIMÉNEZ, J.; TELLES, R.; RODRÍGUEZ, E.; YERENA, J. I.; GARCÍA, D. A.; GÓMEZ, M. Estimación del carbono almacenado en una plantación de *Tectona grandis* L. f. mediante ecuaciones alométricas. **Revista Mexicana de Ciencias Forestales**, México, v. 11, n. 57. p. 32-56, 2020.

LÓPEZ, H.; VAIDES, E.; ALVARADO, A. Evaluación de carbono fijado en la biomasa aérea de plantaciones de teca en Chahal, Alta Verapaz, **Agronomía Costarricense**. San José, v. 42, n. 1, p. 137-153, 2018.

MENA, V. E.; TORRES, J. J.; RUZ, J. C. Estructura florística y carbono almacenado en la biomasa de tres ecosistemas estratégicos del Pacifico colombiano. Revista Cubana de Ciencias Forestales. Pinar del Río, v. 10 n. 1, p. 16-30, 2022.

NACIONES UNIDAS. **La concentración de gases de efecto invernadero alcanza otro récord y van demasiados**. 2023. Disponible en: <https://news.un.org/es/story/2023/11/1525662> Acceso en: 8/01/2024.

PALACIOS, L. Y.; PEREA, K.; BELLIDO, D. M.; CAICEDO, H. Y.; ABADIA, D. Estructura poblacional de ocho especies maderables amenazadas en el departamento del Chocó-Colombia. **Cuadernos de Investigación UNED**. San José, v. 9, n. 1, p. 107 – 114, 2017.

PAYN, T.; CARNUS, J. M.; Peter, F. S.; KIMBERLEY, M.; KOLLERT, W.; Liu, S.; ORAZIO, C.; RODRÍGUEZ, L.; WINGFIELD, M. J. Changes in planted forests and future global implications. **Forest Ecology and Management**. Ámsterdam, v. 352, p. 7, p. 57–67, 2015.

PÉREZ, E.; BONILLA, M. La retención de carbono en plantaciones forestales: estudio de caso Empresa Forestal Integral «Cienfuegos». **Revista Cubana de Ciencias Forestales**. Pinar del Río, v. 2, n. 2, p. 203-213, 2015.

QUICENO, N. J.; TANGARIFE, G. M.; ÁLVAREZ, R. Estimación del contenido de biomasa, fijación de carbono y servicios ambientales, en un área de bosque primario en el Resguardo Indígena Piapoco Chigüiro-Chátare de Barrancominas, departamento del Guainía (Colombia). **Revista Luna Azul.** Manizales, v. 43, p. 171 - 202, 2016.

RANGEL-CH., J. O.; ARELLANO, H. Clima del Chocó Biogeográfico/Costa Pacífica de Colombia. En: RANGEL-CH., J. O. (ed.). **Colombia Diversidad Biótica IV**: El Chocó Biogeográfico/Costa Pacífica. Bogotá: Universidad Nacional de Colombia, 2004, 997 p.

RÍOS, F.; TRIANA, M. Estimación del carbono almacenado en la biomasa aérea de un bosque húmedo tropical en Paimadó, Chocó. Revista Ingenierías USBMed. Medellín, v. 9, n. 1, p. 18-29, 2018.

RODRÍGUEZ, L. A.; GUEVARA, F.; REYES, L.; OVANDO, J.; NAHED, J.; PRADO, M.; CAMPOS, R. A. Estimación de biomasa y carbono almacenado en bosques comunitarios de la región Frailesca de Chiapas, México. **Revista Mexicana de Ciencias Forestales**. Coyoacán, v. 7, n. 37, 77 – 94, 2016.

RODRIGUEZ, N. Guía para la cuantificación de la biomasa y el carbono forestal, generación de modelos y uso de herramientas para su estimación. CORPORACIÓN AUTONÓMA REGIONAL DE CUNDINAMARCA – CAR, Subdirección de Administración de los Recursos Naturales y Áreas Protegidas, Bogotá D.C., Disponible en: https://www.car.gov.co/uploads/files/5ade19e5bcb8e.pdf. Consultado el: 29/05/2024.

SÁNCHEZ, N. I.; IRÍAS, N. A.; CALERO, G. C.; ALONZO, S. E. Biomasa forestal, carbono fijado y almacenado en sistema bosque y sistema silvopastoril en siete fincas del municipio de Mulukukú, RACN, 2018. **La Calera Revista Científica**. Managua, v. 20, n. 34, p. 49 – 56, 2020.

SERNA, Y. B.; GONZÁLEZ, F. R. Usos de residuos de cosecha forestal, como alternativa económico-ambiental de paisajes más sostenibles en bosques húmeros tropicales del Chocó. En: CHACÓN, L. (ed**.). Las Agrociencias en la dimensión de paisajes sostenibles**. Bogotá, DGP Editores, Ediciones Unisalle, 2022, p. 90-119.

TORRES, J. J.; MEDINA, H. H.; MARTÍNEZ, M. Caracterización del aprovechamiento forestal como herramienta para el manejo del bosque natural en el Medio Atrato. **Revista Biodiversidad Neotropical.** Quibdó, v. 9, n. 4, p. 1-14, 2019.

TORRES, J. J.; MENA, V. E.; ÁLVAREZ, E. Carbono aéreo almacenado en tres bosques del Jardín Botánico del Pacífico, Chocó, Colombia. **Entramado.** Cali, v. 13, n. 1. p. 200-209, 2017.

IUCN. *Humiriastum procerum* has most recently been assessed for the IUCN Red List of Threatened Species in 2019. *Humuriastrum procerum* is listed as Vulnerable under criteria A4cd. Disponible en: <https://www.iucnredlist.org/species/144823011/145025929> consultado e: 15/01/2024.