Research Article

CARBON STOCK, RATES OF CARBON ACCUMULATION AND DISTRIBUTION OF PARTICLES IN A LAKE OF THE ANAVILHANAS ARCHIPELAGO, NEGRO RIVER - AMAZON DURING THE LAST 1900 YEARS

Estoque de carbono, taxas de acumulação de carbono e distribuição de partículas em um lago do Arquipélago de Anavilhanas, Rio Negro - Amazônia durante os últimos 1900 anos

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ABSTRACT: Recent studies show that, despite great variability, the lake systems of the Amazon Basin have presented significant results in the accumulation and storage of organic carbon (TOC). However, the demonstration in the region is still limited and lacks more data to better estimate this non-carbon component of the region. The objective of this article was to estimate the carbon stock, the carbon accumulation rates and characterize the granulometric distribution of an Amazonian lake located in the Anavilhanas Archipelago, in the Lower Negro River region. Data were carried out using the 14C method and analyses of density, granulometry and TOC rate sof samples of a sediment core 1 meter deep. The results have shown that, during the period of 1900 cal years BP, Lake Boto presented two isolated peaks of sand particle sedimentation possibly related to major hydrodynamic events. Generally, well-defined characteristics of a lacustrine environment with sedimentation of fine silt and clay particles predominate. The sedimentation rate was 0.03 cm.year^{-1} between approximately 1900 to 850 cal years BP and 0.07 cm.year-^{1} in the last 850 cal years BP. It is estimated that Lake Boto has a stock of approximately 231,000 tons of TOC accumulated during the entire period. The stock of TOC is not significant as it is estimated for the soils of the Amazon. The results are an important indication of the role of the Anavilhanas Archipelago as a TOC sink.

Keyword: Amazon; Carbon stock; Lake systems;

RESUMO: Estudos recentes mostraram que, apesar da grande variabilidade, os sistemas lacustres da Bacia Amazônica têm apresentado resultados significativos no acúmulo e armazenamento de carbono orgânico (COT). No entanto, a amostragem na região ainda é limitada e carece de mais dados para melhor estimar este componente no orçamento de carbono da região. O objetivo deste artigo foi estimar o estoque de carbono, as taxas de acumulação de carbono e caracterizar a distribuição granulométrica de um lago amazônico localizado no Arquipélago de Anavilhanas, no baixo Rio Negro. Foram realizadas datações pelo método 14C e as análises de densidade, granulometria e teor de COT de amostras de um núcleo sedimentar de um metro de profundidade. Os resultados mostraram que, durante o período de 1900 anos cal AP, o Lago Boto apresentou dois picos isolados de sedimentação de partículas de areia possivelmente relacionados a eventos de maior hidrodinâmica. Em geral, predominaram características bem definidas de um ambiente lacustre com a sedimentação de partículas finas de silte e argila. A taxa de sedimentação foi de 0,03 cm.ano-^{1} entre aproximadamente 1900 a 850 anos cal AP e de 0,07 cm.ano-^{1} nos últimos 850 anos cal AP. Estima-se que o Lago Boto tenha um estoque de aproximadamente 231.000 toneladas de COT acumulado durante todo o período. O estoque de COT nesse lago é tão significativo quanto o estoque estimado para os solos da Amazônia. Os resultados são uma indicação importante do papel do Arquipélago de Anavilhanas como um sumidouro de COT.

Palavras-chave: Amazônia; Estoque de carbono; Sistemas lacustres.

RESUMEN: Estudios recientes muestran que, pese a la gran variabilidad, los sistemas lacustres de Bacia Amazônica presentan resultados significativos en acumulación y armamento de carbono orgânico (COT). Sin embargo, el amostragem na región aún es limitado y carece de más datos para estimar mejor este componente no orçamento de carbono de la región. El objetivo de este artículo es estimar el estoque de carbono, como taxas de acumulación de carbono y caracterizar la distribución granulométrica de un lago amazónico localizado en el Arquipélago de Anavilhanas, en el bajo Río Negro. Foram realizó datações pelo método 14C e as análises de densidade, granulometria e teor de COT de demostraciones de un núcleo sedimentar de un metro de profundidade. Los resultados muestran que, durante el período de 1900 años cal AP, el Lago Boto presentó dos picos aislados de sedimentación de partículas de área posiblemente relacionadas con eventos de mayor hidrodinámica. En general, predominan las características definidas de un ambiente lacustre con sedimentación de partículas finas de sedimento y argila. A taxa de sedimentação foi de 0,03 cm.ano^{-1} entre

aproximadamente 1900 a 850 años cal AP y de 0,07 cm.ano^{-1} en los últimos 850 años cal AP. Se estima que el Lago Boto tiene un estoque de aproximadamente 231.000 toneladas de COT acumuladas durante todo el período. El estoque de COT nesse lago es tan significativo cuanto el estoque estimado para los solos de Amazônia. Los resultados son una indicación importante del papel del Arquipélago de Anavilhanas como un sumidouro de COT.

Palavras clave: Amazonas; Reservas de carbono; Sistemas lacustres.

INTRODUÇÃO

The Amazon Basin comprises a vast territory in the northern portion of South America, extending over 6,106 km² and encompassing an area that spans seven countries (FILIZOLA and GUYOT, 2011). Approximately 44% of this area corresponds to fluvial plains (GUYOT et al., 2007). These plains are dynamic and complex environments, exhibiting seasonal oscillations of water levels and constant sediment exchange with the channels and flood lakes (várzeas). They are also considered significant environments for the production, storage, and export of carbon (MOREIRA-TURCQ et al., 2004; MOREIRA-TURCQ et al., 2013).

Carbon accumulation in lakes within the Amazon Basin has been demonstrated to be substantial compared to lakes in other regions of the world, with markedly higher accumulation rates, despite the considerable variability. However, sampling in the region is still limited and more data is needed to better estimate this potentially important component in the Amazon Basin's carbon budget (SANDERS et al., 2017).

The representativeness of continental aquatic systems in global-scale carbon assessments remains limited (COLE et al., 2007; AUFDENKAMPE et al., 2011), despite them being considered important agents in the coupling of biogeochemical cycles between the continent, atmosphere, and oceans (AUFDENKAMPE et al., 2011). Understanding the role of these systems in the carbon cycle can be of fundamental importance for the maintenance of these ecosystems and for understanding how they may react to current and predicted future climate change, especially in the Amazon region, which plays a crucial role in modulating the climate both regionally and globally (NOBRE et al., 2009).

In this context, the objective of this work was to estimate the carbon stock, carbon accumulation rates and to characterize the particle size distribution in a lake of the Anavilhanas Archipelago - the lower course of the Negro River, Amazon, Brazil.

MATERIALS AND METHODS

Environmental settings

The Negro River is the largest tributary on the left bank of the Amazon River and the primary blackwater river in the basin. It boasts an average annual net discharge of 29,000 m³/s and drains an area of 696,000 km² (FILIZOLA, 1999). Characterized by an equatorial regime, it experiences a peak in high water levels during the middle of the year (MOLINIER et al., 1996). In its lower course, the river levels are significantly influenced by the Solimões River due to hydraulic damming affecting all its tributaries (MEADE et al., 1991; FILIZOLA et al., 2011).

The reddish-brown (black when in large volume) color of the Negro River's waters is attributed to humic substances leached from podzolic soils in the region. These waters are considered acidic, with a pH ranging from 4-5 (JUNK et al., 2015). With a low concentration of suspended sediments, approximately 7.9 mg/L (SIOLI, 1984), the river discharges an average of 8,000,000 tons per year of sediments into the Solimões-Amazon system (FILIZOLA and GUYOT, 2011), a relatively small amount compared to its net discharge (LATRUBESSE and STEVAUX, 2015).

The climate of the lower Negro River region is characterized as rainy tropical or equatorial, with consistently high temperatures ranging from 25 to 28ºC on a monthly basis. The annual amplitude is less than 3º, and rainfall is abundant and well-distributed throughout the year (Ayoade, 1996). The Negro River basin experiences one of the highest annual precipitations in the Brazilian Amazon, averaging between 2000 to 2200 mm (SOMBROEK, 2001). In certain border areas between Brazil, Venezuela, and Colombia, this value can reach 3500 mm (FISCH et al., 1998).

The Anavilhanas Archipelago is situated in the lower course of the Negro River, characterized by an anabranch pattern with multiple channels separated by islands, featuring interior lakes (LATRUBESSE and STEVAUX, 2015) (Fig. 1). The islands are formed by fine sediments covered with vegetation, flooded during high-water periods by igapós, and during low-water periods, they expose steep banks that can reach approximately 7 meters above the minimum flow (LATRUBESSE and FRANZINELLI, 2005). The biota of igapós is considered highly sensitive to changes in the hydrological cycle (JUNK et al., 2015). The lake complex of the Anavilhanas Archipelago has a strong relationship with the river regime of the Negro River and functions as a reservoir for water and materials transported in suspension (MARINHO, 2020).

Boto Lake (LBT-15-03) (S 02º27.508' and W 60º58.779') is located within a river island of the Anavilhanas Archipelago, near the left bank of the Negro River, upstream of the Novo Airão municipal seat (Figure 1). Access is only possible by river through the connection channel with the main channel or through the "igapó" areas during high waters. The lake is situated in an area protected as a National Park, encompassing more than 350,000 ha, with international importance for the maintenance of biodiversity recognized through the Ramsar Convention (MMA, 2018).

The region where Boto Lake is located features wide islands with the largest lakes in the archipelago, predominantly connected by connecting channels to the main channel regime. The surface area of the existing lakes varies about 16.97% under conditions close to the fluviometric averages between low and high waters of the Negro River (SILVA et al., 2020). In an upstream section of the archipelago, Marinho (2019) observes an average net discharge on the order of 26,094 m³/s and velocities of 0.58 m/s. In extreme events, this variation becomes more pronounced, as observed by Almeida-Filho et al. (2016) and Marinho et al. (2017) in analyses conducted in the region. Boto Lake is connected to the Negro River in the southern part by a channel that is approximately 800 meters long and 150 meters wide. It has an irregular elongated shape, similar to the shape of the island where it is located. In its interior, there is an island about 1 km long and 500 m wide (Figure 1). Its total surface area varies from 10,906 km² to 15,105 km² between low and high water periods.

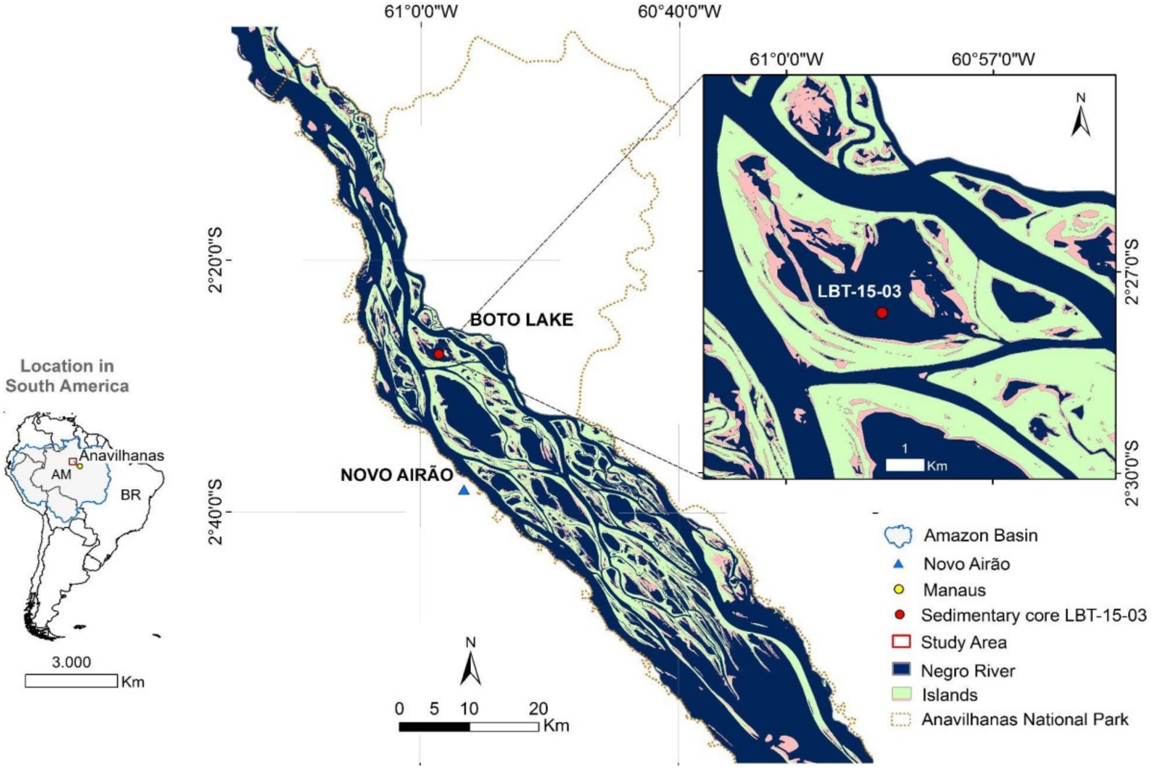

Figure 1. Location of the study area in the Negro River and the collection point of core LBT-15-03 at Boto Lake.

SAMPLING AND ANALYTICAL PROCEDURES

The sedimentary core LBT-15-03 was collected in Boto Lake - Anavilhanas Archipelago, using a "vibra-core", which consists of a concrete vibrator with a 3mm thick and 7.5 cm diameter aluminum tube attached to the tip. The core was opened in a longitudinal section in the Sedimentology Laboratory of the Universidade Federal Fluminense - UFF, with the aid of a circular saw. After the opening, its sedimentological, macroscopic (texture) and optical (color) characteristics were described, and sub-samples were separated for analysis.

Radiocarbon dating

The ^{14}C dating of 2 samples were performed by Accelerator Mass Spectrometer (AMS) NEC SSAMS at Beta Analytic and Institut de Recherche Pour le Développement (IRD). Due to the natural variations of 14C in the atmosphere, the ages obtained were calibrated using the IntCal13.14C curve in the Calib 7.1 program (available on the internet at (http://radiocarbon.pa.qub.ac.uk/calib/). Thereafter, the ages were expressed in cal years BP (before the present). The age-depth chronological model was built from calibration (IntCal13 curve) and data interpolation in the Bacon Package in R software and can be found in Cordeiro et al (Submitted).

Water content and Bulk density

After opening the core, containers of known weight and volume were used to perform sub-sampling every 1 cm, totaling 100 sub-samples. The aliquots were weighed and taken to an oven at 40º C for several days until a stable dry weight was obtained. The water content and bulk density were determined by the following ratios:

$$\textit{Water content} = W(\%) = ((Ww - Wd)/Ww)x100)$$

Where, Ww is the mass of the wet sample and Wd is the mass of the dry sample.

$$\textit{Bulk density} = Bd = Wd(g)/V(cm^{-3})$$

Where, Wd is the mass of the dry sample and V refers to the volume of the container.

Particle size analysis

The 50 sub samples, selected every 2 cm, were treated with hydrogen peroxide (H2O2) to remove organic matter and then with sodium hexametaphosphate (Na16P14O43 – 40 $g.L^{-1}$) to disperse the particles. The readings were taken in the CILAS® 1064 Particle Analyzer, in the Sedimentology Laboratory of the Universidade Federal Fluminense. The results were submitted to particle size classification according to the particle diameter.

Total Organic Carbon - TOC

To determine Total Organic Carbon contents (TOC), 100 sub-samples were analyzed. The samples were dried, macerated, packed in tin capsules and sent for analysis. The TOC determinations were performed with the Delta V IRMS (Isotope Ratio Mass Spectrometer) interfaced with Flash EA at Southern Cross University, Australia.

Sedimentation rates and carbon accumulation rates

The sedimentation rate corresponds to an estimate of the amount of material sedimented per year. Its calculation was made through the ratio between two depths and their respective dates, where the result is expressed in $cm.year^{-1}$.

The carbon accumulation rates were calculated by multiplying the TOC concentration by the bulk density of each sample. Finally, this value was multiplied by the sedimentation rate, obtaining the result expressed in $g.cm^{-2}.year^{-1}$, as represented by the following equation:

$$\textit{Carbon Accumulation Rate} = TOC \times Bd\ (g.cm\text{-}3) \times Sr\ (cm.yr^{-1})$$

Where,

TOC corresponds to the total organic carbon content, Bd is the bulk density and Sr is the sedimentation rate. Subsequently, the result was converted to $g.m^{-2}.yr^{-1}$.

Total Organic Carbon Stock

For the estimation of the Total Organic Carbon Stock the lake area during the low water period was used, corresponding to 10906 km². The choice was made because this area remains with water during the entire hydrological year, except for extreme events. Thus, it possibly presents a more homogeneous TOC accumulation.

Initially the volume of the lake corresponding to the depth of each sample analyzed was calculated, being 1 cm for each one. In order to calculate the volume, the shape of a cylinder was used as a reference, according to the following equation:

$$\textit{Lake Volume}\ (cm^3) = Vl\ (cm^3) = \textit{Depth}\ (cm) \times \textit{Lake area}\ (cm^2)$$

Subsequently, the accumulated carbon stock for the lake volume at each 1 cm depth was calculated according to the following equation:

$$C\ stock\ (t) = TOC\ (gC.gS) \times Bd\ (g.cm^3) \times (Vl\ (cm^3)/\ 1{,}000{,}000)$$

Where, TOC corresponds to the weight of carbon contained in 1g of sediment (gC.gS); Bd corresponds to the bulk density of the sample ($g.cm^{-3}$); Vl to the volume of the lake at 01 cm depth (cm³). The result was converted to tons.

RESULTS AND DISCUSSION

Lithology and Chronology

Based on the lithological description, dating, granulometric data and the behavior of the geochemical results, sedimentary deposit LBT-15-03 was divided into two phases. Phase II, which corresponds to the basal portion of the sedimentary deposit, refers to the depth between 100 and 58 cm and phase I, which corresponds to the depth from

57 to 0 cm, as detailed below.

Five intervals of distinct coloration for the sedimentary core were identified with the help of the Munsell chart. The intervals consist of: 100 - 80 cm - 5 YR 3/1 (very dark gray); 79 - 73 cm - 10 YR 3/1 (very dark gray); 72 - 56 cm - 10 YR 4/1 (dark gray); 55 - 44 cm - 10 YR 3/1 (very dark gray) and 43 - 0 cm - 7.5 YR 3/2 (dark brown).

For the 1-meter interval of the core samples studied, two samples were dated using the 14C method. The oldest sample was 1840 cal years old (Table 1).

Table 1. 14C dating with cal BP

Sample (Depth)	Radiocarbon age	cal BP ages (Calib 7.1)	Calibrate age (cal years BP)
60 cm	950 +/- 30 BP	795 – 926	854
95 cm	1890 +/- 30 BP	1735 – 1893	1840

For phase II, the sedimentation rate determined was 0.03 $cm.year^{-1}$, associated with the depth between 95 and 60 cm. While for phase I, a sedimentation rate of 0.07 $cm.year^{-1}$ was identified, corresponding to the last 60 cm deposited.

Bulk density and water content

Phase II presented density ranging between 0.54 $g.cm^{-3}$ and 0.98 $g.cm^{-3}$, with an average of 0.80 $g.cm^{-3}$ and water content ranging between 48.3% and 57.4%, with an average of 52.3% (Figure 2). The carbon content varied between 2.1% and 3.2%, with an average of 2.7%. In phase I the density varied between 0.26 $g.cm^{-3}$ and 0.67 $g.cm^{-3}$, with an average of 0.47 $g.cm^{-3}$, the water content varied between 57.0% and 71.3%, with an average of 66.0% and the carbon content varied between 3.2% and 6.7% with an average of 4.5%.

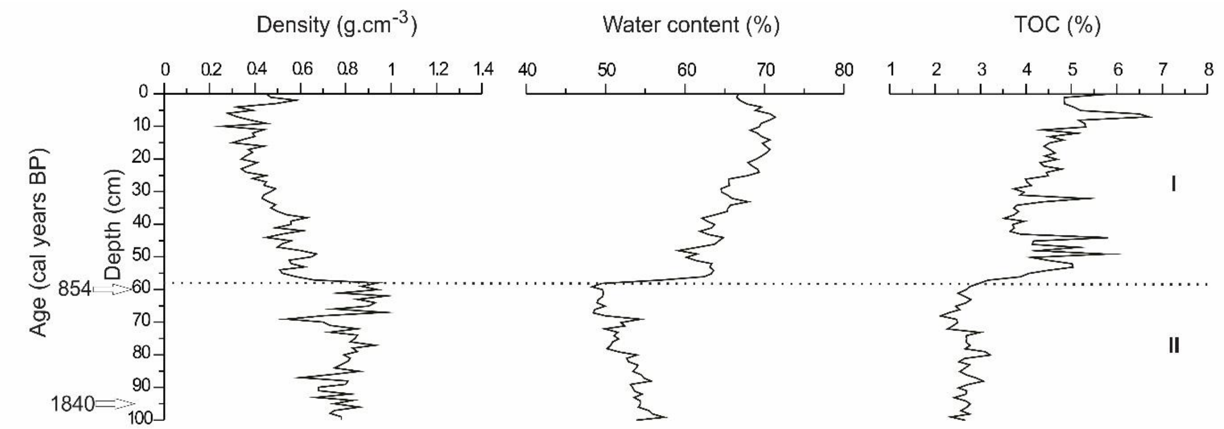

Figure 2. Values of density ($g.cm^{-3}$), water content and total organic carbon (C contents).

Grain size fractions

The particle size distribution of the sediment profile showed high values of silt and clay particles for both phases (Table 2). In phase II the average clay was 26.7%, very fine silt 19.2%, fine silt 25.4% and medium silt 19.7%. In phase I the average clay was 27.2%, very fine silt 18.3%, fine silt 24.2% and medium silt 19.5%. For coarse silt, the average in phase II was 4.2% and in phase I 4.6%. For very coarse silt, an occurrence was only identified in phase II, with an average percentage of 0.3%.

Table 2. Minimum, average, and maximum particle size values for each particle size fraction analyzed.

Phase		% Med.Sand	% Fine Sand	% Very fine sand	% Very coarse silt	% Coarse silt	% Med. Silt	% Fine silt	% Very fine silt	% Clay
I	Minimum	0	0	0	0	0	0	2.9	5.0	15.2
	Medium	2.6	3.6	0	0	4.6	19.5	24.2	18.3	27.2
	Maximum	67.5	50.3	0	0	12	25	28.4	21.8	31.4
II	Minimum	0	0	0	0	0	4.19	12.1	9.97	16.0
	Medium	0.85	0.7	0	0.3	4.2	19.7	25.4	19.2	29.7
	Maximum	17.9	15.2	0	5.4	17.3	29.6	36.2	24.8	34.8

The occurrence of sand in the sedimentary deposit is associated with an isolated peak in phase II, at a depth of 98 cm, with an average of 33.2%, and another isolated peak in phase I, between 16 and 12 cm depth, with an average of 62.0% (Figure 3). At the other depths the occurrence of sand particles is not recorded.

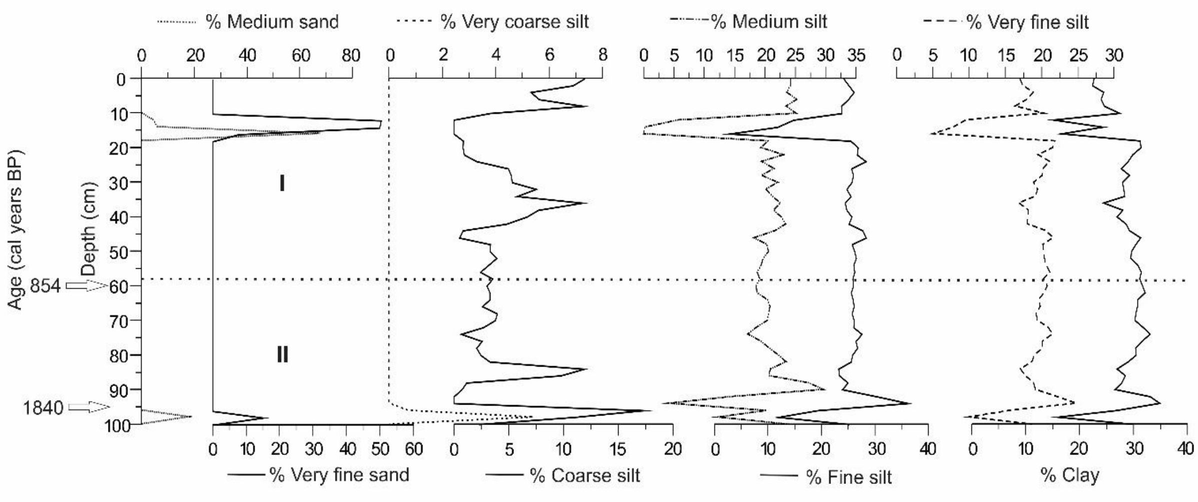

Figure 3. Values of grain size.

Dynamics of TOC accumulation in Boto Lake

It is possible that carbon accumulation in Lake Boto directly influences the environmental characteristics and hydrodynamics of the Rio Negro.

During periods of high water, the Negro River connects with the lake through the overflow of the runoff, flooding the surrounding vegetation areas, forming the igapós. Thus, the hydrodynamics of the lake is consequently altered with the increase of energy in the environment, which possibly contributes to the entrance of sediments into the lake. During the low water periods, the influence of the Negro River is reduced, being conditioned especially to the existing connection channel. With the lake hydrodynamics altered by the reduction of energy in the environment, the external sediment input possibly decreases (Figure 4).

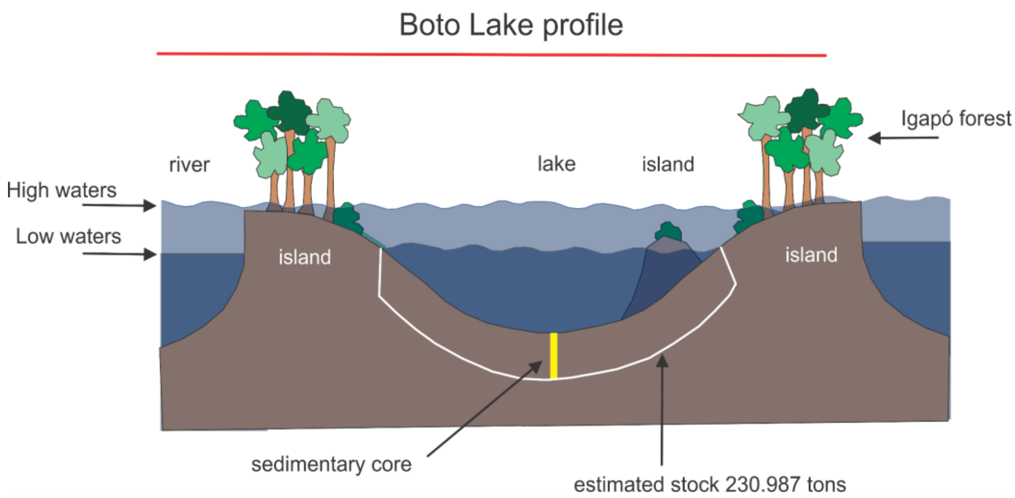

Figure 4. Schematic of the environmental conditions of Boto Lake and estimated accumulated stock for 100 cm depth during 1900 cal years BP.

The phases analyzed at the Boto Lake core site exhibit well-defined characteristics. with a predominance of fine sediment deposition (silt and clay). For phase II, carbon accumulation rates ranged between 4.80 g.m^{-2}.year^{-1} and 23.17 g.m^{-2}.year^{-1} with an average of 9.90 g.m^{-2}.year^{-1} (Figure 4). The estimated carbon stock for the lake in this phase was 99,685 tons.

Two peaks representing occurrences of sand particles are associated with periods of increased hydrodynamics in the lake. These sandy intervals may also result from extreme flood events, leading to sedimentation packages during one or several successive extreme flood events (MOREIRA-TURCQ et al., 2014). Similar situations have been observed in other Amazonian flood lakes (QUINTANA-COBO et al., 2018).

Recent studies note the presence of sand in various compartments of the archipelago. Marinho (2019) observed coarse suspended particles (> 63 μm) at around 10% during periods of lower net discharge. Alves (2013) identified extensive sandy bars along the channels of the archipelago exposed during low water periods. Barbosa (2015) recorded the occurrence of sand in the substrate of the islands of the archipelago, although fine particles of silt and clay predominate. Cunha (2017), in fancier analyses, indicates the presence of sandy layers alternated with muddy layers in the substrate composition of the islands.

Moreira et al. (2012; 2013) and Aniceto et al. (2014) record for the floodplain lakes Santa Ninha, Comprido and Quistococha that the increase of fluvial influence increases the accumulation of carbon in the lakes even if they have low TOC contents. This is due to the dilution of organic matter by the large amount of deposited mineral sediments (ANICETO et al., 2014; CONTRERA, 2017). In Boto Lake there was a general increase in TOC percentages and sedimentation rates over the last 854 cal years BP.

The Airo Lake located on the right bank of the Negro River upstream of Anavilhanas, Contrera (2017) observed that the period of low fluvial influence (last 3000 cal years BP) was characterized by lake isolation, where sedimentation rates were 0.009 cm.year^{-1} and an increase in mean TOC concentration occurred to 34.15%, however TOC accumulation rates averaged approximately 3.48 g.m-^{2}.year^{-1}. Also in Airo Lake, the author identified for the period of greatest fluvial influence, average TOC contents of 1.40% and high sedimentation rate, on the order of 0.385 cm.year^{-1} causing average carbon accumulation rates of 52.48 g.m^{-2}.year. Aniceto et al (2014) also observe increased TOC concentrations during periods of isolation of Quistococha Lake (2600 cal years BP), ranging from 10 to 40% sedimentation rates on the order of 0.02 cm.year^{-1} and TOC accumulation rates between 5 and 8 g.m^{-2}.year^{-1}.

For phase I, carbon accumulation rates ranged from 9.71 g.m^{-2}.year^{-1} to 27.63 g.m^{-2}.year^{-1} with an average of 14.86 g.m^{-2}.year^{-1}. The estimated carbon stock for the lake in this phase was 131,302 tons.

In Acarabixi Lake, also located in the middle Negro River region, Cordeiro et al (2008) recorded that the last 20 years, as noted through the ^{210}Pb dating method, were marked by high sedimentation rates and high carbon contents and, subsequently, high

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carbon accumulation rates. In this period, Acarabixi Lake reported a sedimentation rate of 0.41 cm.year^{-1}, an average TOC content of 25% and average carbon accumulation rate of 265 g.m^{-2}.year^{-1}.

With the available data it is still not possible to determine the cause of the small variations observed in the Boto Lake core. Differences in results between Boto Lake and other lakes studied in the Negro River Basin (CORDEIRO et al, 2008; CONTRERA, 2007) may be attributed to the distinct characteristics of these lakes. Airo and Acarabixi lakes are located on the margins of the Negro River, while Boto Lake is situated on an island inside the archipelago.

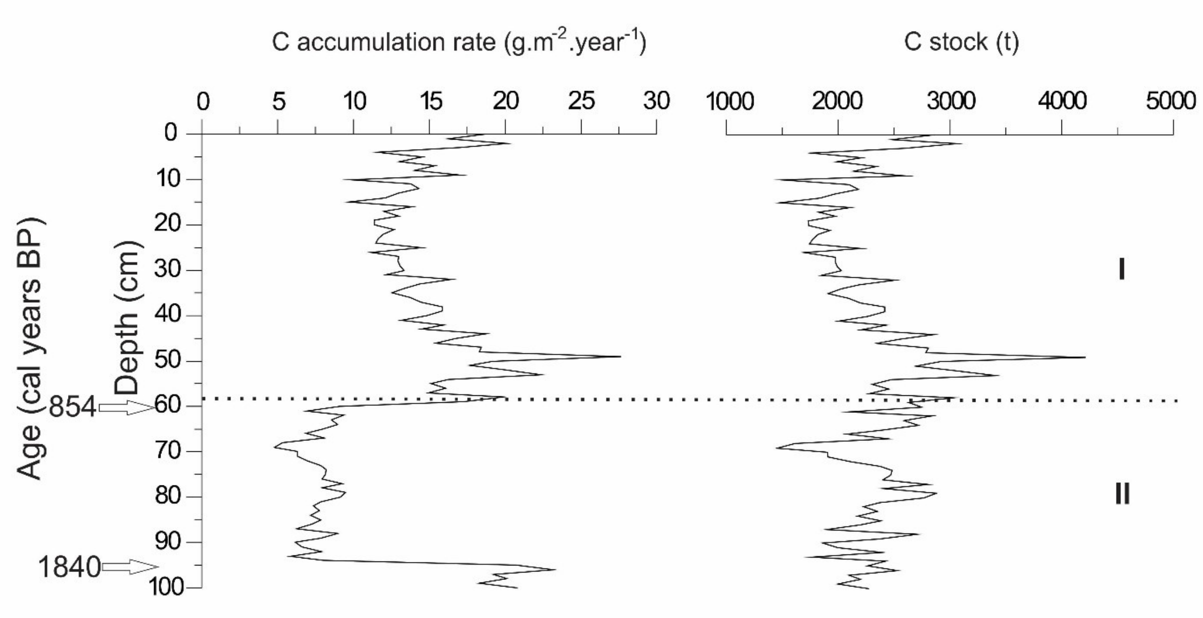

Figure 5. Carbon accumulation rates and Carbon stock.

Carbon Stock

During the last 1880 cal years, BP Boto Lake had a storage of approximately 230,987 tons of TOC. This stock corresponds to a sediment depth of 100 cm and an area of 10.906 km². In the Peruvian Amazon, Quistococha Lake (which covering an area of about 0.50 km²) is estimated to have a TOC stock of approximately 6,846 tons for a depth of 60 cm representing the last 2700 cal years BP. During this period, the lake's palaeohydrological conditions were characterized by decreased fluvial influence due to its isolation (ANICETO et al., 2014). Lake Quistococha is similar to Boto Lake as both have black water.

Comparing the carbon stocks determined in these lakes (Figure 6b) with those estimated for soils in the Amazon region reveals similarities. Cerri et al (2007) used the Century Model to estimate that soil carbon stocks in the Brazilian Amazon in the 0 to upper 20 cm layer vary between 20 to 150 tonC.ha^{-1} (1 Mg = 1 ton) with values between 60 to 80 tonC.ha^{-1} found in most of the region. The TOC stocks in the sediments of lakes located in the floodplains of the main Amazonian rivers are as significant as the stocks recorded for the same depth in adjacent soils. In Boto Lake, an approximate stock of 40 $ton.ha^{-1}$ was estimated for a depth of 0 to 20 cm.

Quistococha Lake located in the floodplain of the Amazon River, showed similar values for this depth, with an accumulated stock of 44 $ton.ha^{-1}$. Aniceto et al (2014) identifies that the organic matter of this lake is currently predominantly influenced by the surrounding vegetation, with little contribution from aquatic autotrophic biomass. For Lagarto Lake, located in the floodplain of the Marañon River, the storage referring to this depth was approximately 131 $ton.ha^{-1}$ a value three times greater than that of lakes Boto and Quistococha. Quintana-Cobo et al. (2018) point out that the organic sedimentation of this lake reflects significant contributions from the local watershed and probably primary production in situ.

In the floodplain lakes at the confluence of the Marañon and Ucayali rivers, stocks were lower for this depth (Figure 6a and 6b). For Hubus Lake, a stock of 19 $ton.ha^{-1}$ was estimated. For La Moringa Lake, a stock of 30 $ton.ha^{-1}$ was estimated. For Carmem Lake, a stock of 15 $ton.ha^{-1}$ was estimated. Hubus, Carmem and La Moringa lakes received greater fluvial influence during the analyzed period. This may be related to the combined effects of fluvial geomorphological processes of channel migration and paleoclimatic changes during the Late Holocene (QUINTANA-COBO et al., 2018).

In the lower course of the floodplain of the Amazon River, in Santa Ninha Lake, a stock of 14 $ton.ha^{-1}$ was estimated for this same 20 cm depth. Santa Ninha Lake is part of a group of approximately 30 lakes permanently connected to the Amazon River by small channels (MOREIRA et al., 2012). Santos (2022) estimates that at the Itacoatiara station, located upstream of Lake, the Amazon River has a load of 1421 Mt $year^{-1}$ of sediments.

Cerri et al (2007) estimate that it is also possible to observe that the regions which presented the greatest accumulation of carbon in the first 20 cm of Amazonian soils are associated with regions adjacent to the floodplain, where the greatest contribution to the stocks comes from soils under native vegetation and present values between 100 and 150 $tonC.ha^{-1}$.

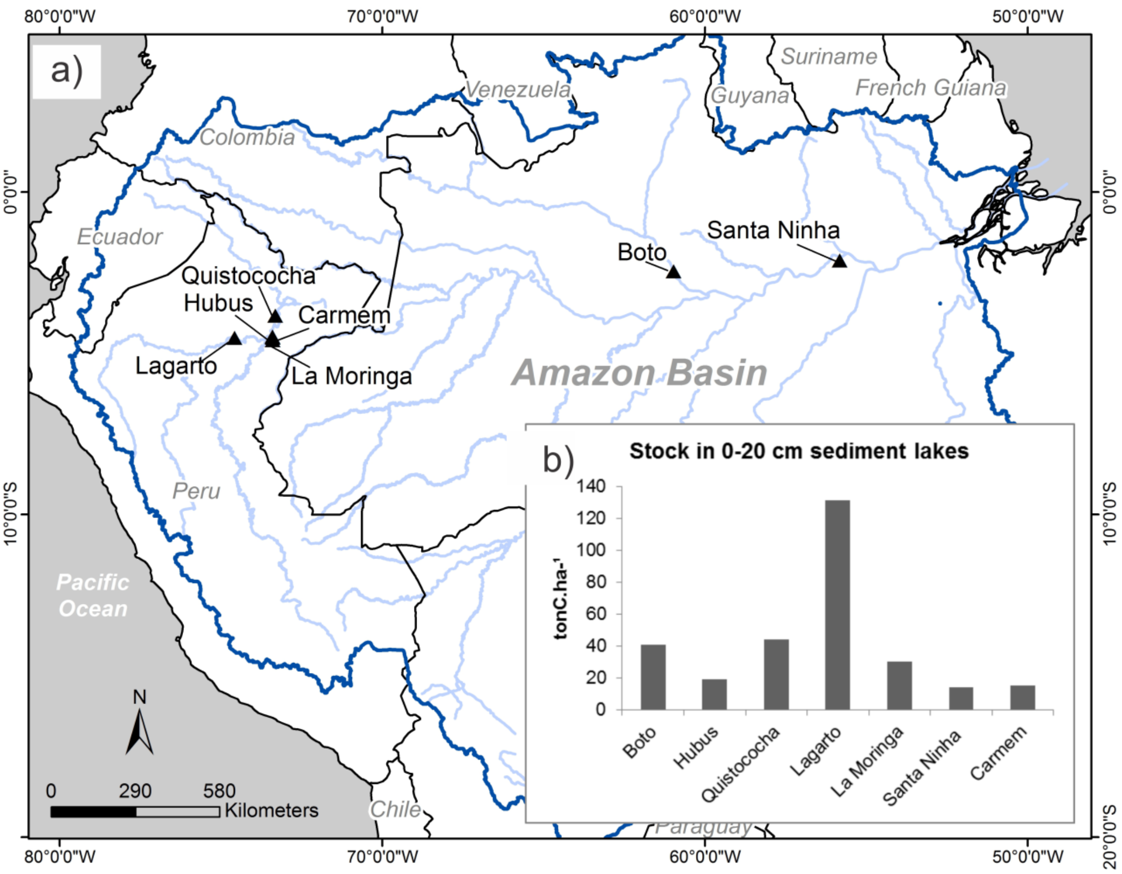

Figure 6. a) Location of lakes and estimated TOC stock at a depth of 0-20 cm in sediments. value calculated per hectare; b) Data obtained from Cordeiro et al. (Submitted); Moreira (2008); Moreira et al. (2012); Aniceto et al. (2014); Quintana-Cobo et al. (2018).

CONCLUSIONS

The results allow us to estimate that during the last 1900 cal years BP, a stock of 231,000 tons of TOC was accumulated at a depth of one meter in Lake Boto. Throughout this period, well-defined characteristics of a lacustrine environment with sedimentation of fine silt and clay particles have predominated, marked by increases in carbon accumulation rates over the last 850 cal years BP. To better understand this increase, it is necessary to characterize the source of organic matter in this lake and understand the percentage of external and local influence.

The particle size oscillations recorded may be the result of changes in the hydrodynamics of the Negro River due to extreme flooding events or changes in the input of sediments from the Branco River. Although previous studies indicate the presence of sandy sediments in different portions of the archipelago and suggest the possible origin of this material for the lake, understanding the cause of the events that caused this deposition requires more data, such as more detailed dating and association with other geochemical parameters.

When compared with other Amazonian lakes, it is observed that environmental

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characteristics significantly influence accumulation rates. Blackwater lagoons, partially or totally isolated from the river's fluvial dynamics, showed greater TOC storage per hectare. Meanwhile, the lakes located in the alluvial plains of the white water rivers, Marañon, Ucayali and Amazonas, showed lower sediment storage for the depth of 0-20 cm.

The results obtained provide initial insights into the dynamics of carbon accumulation in the Anavilhanas Archipelago and its stock potential. The relevance of continuing studies on this theme is accentuated due to the large number of lakes and the existing fluvial dynamics.

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