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CONDITIONING FACTORS OF "TERRAS CAÍDAS" IN LOWER SOLIMÕES RIVER - BRAZIL

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ABSTRACT

The term "*Terras Caídas*" is used in Amazon to refer to processes of fluvial erosion and mass movements of large and moderate scale. It is a dynamic and complex multi-causal process that involves hydrodynamic, hydrostatic, climatic, neotectonic, lithological and anthropic factors, occurring together or separately. The objective of this work is to understand the conditioning factors of the phenomenon "*Terras Caídas*" in lower Solimões River - Brazil. For this purpose, the study area was monitored for 2 years (2017-2018) and data from satellite images; water discharge; flow velocity; suspended sediments; water level; precipitation; wind direction; seismic activity were obtained. The hydrodynamic factors and the rain influence the "*Terras Caídas*" more intensely during the river flood, the processes influenced by the wind direction occur throughout the hydrological year, but with greater intensity during storms. Hydrostatic pressure occurs more frequently in ebb causing landslides. The lithology influences the stability of the banks due to unconsolidated sediments, providing erosion and mass movements. It is observed that neotectonics was not important in increasing the intensity of the "*Terras Caídas*" in the study area in recent years. Human activity influences destroying riparian forests and the basal erosion caused by waves formed by boats in the region.

Keywords: "*Terras Caídas*". Amazon. Solimões River. Erosion. Mass Movement.

FATORES CONDICIONANTES DAS TERRAS CAÍDAS NO BAIXO RIO SOLIMÕES - BRASIL

RESUMO

O termo "Terras Caídas" é usado na Amazônia para designar processos de erosão fluvial e movimentos de massa de larga e moderada escala. É um processo dinâmico e complexo multicausal que envolve fatores hidrodinâmicos, hidrostáticos, climáticos, neotectônicos, litológicos e antrópicos, ocorrendo em conjunto ou separados. Este trabalho tem como objetivo compreender os fatores condicionantes do fenômeno das "Terras Caídas" no baixo rio Solimões – Brasil. Para isto a área de estudo foi monitorada durante dois anos (2017-2018) e foram obtidos dados de imagens de satélite; descarga de água; velocidade de fluxo; sedimentos em suspensão; nível da água; precipitação; direção do vento; atividade sísmica. Os fatores hidrodinâmicos e a chuva influenciam as "Terras Caídas" de forma mais intensa durante a cheia, os processos influenciados pela direção do vento ocorrem ao longo de todo o ano hidrológico, mas com maior intensidade durante as tempestades. A pressão hidrostática ocorre com maior frequência na vazante, causando deslizamentos. A litologia influencia na estabilidade das margens devido a sedimentos inconsolidados, proporcionando erosão e movimentos de massa. Observa-se que a neotectônica não foi importante no aumento da intensidade das Terras Caídas na área de estudo nos últimos anos. A atividade humana influencia desmatando matas ciliares e na erosão basal causada pelas ondas formadas por barcos na região.

Palavras-Chave: "Terras Caídas". Amazônia. Rio Solimões. Erosão. Movimento de Massa.

INTRODUCTION

The term "*Terras Caídas*" has been widely used in the academic community by Tricart (1977); Sternberg (1998); Carvalho (2006; 2012); Igreja, Carvalho e Franzinelli (2010); Magalhães (2011); Freitas e Albuquerque (2012); Guerra e Guerra (2015); Marques (2017); Magalhães e Vieira (2018); Bandeira *et al.* (2018), among others. According to Carvalho (2006; 2012) this is the Amazonian term used by *ribeirinhos* (riverside people) to designate river erosion processes. However, "*Terras Caídas*" phenomenon is unique in the world, as it involves, in addition to fluvial erosion, moderate and large mass movements (BANDEIRA *et al.,* 2018).

The process occurs with greater intensity in the Andean rivers (white water rivers) (CARVALHO, 2006; 2012). However, in rivers with clear and black waters the process also occurs on a smaller scale (IGREJA; CARVALHO; FRANZINELLI, 2010; BANDEIRA *et al*., 2018). Often the phenomenon takes on catastrophic proportions and can cause material damage and loss of life and adding large amounts of sediment and organic matter in river (CARVALHO, 2006; 2012; GUERRA and GUERRA, 2015).

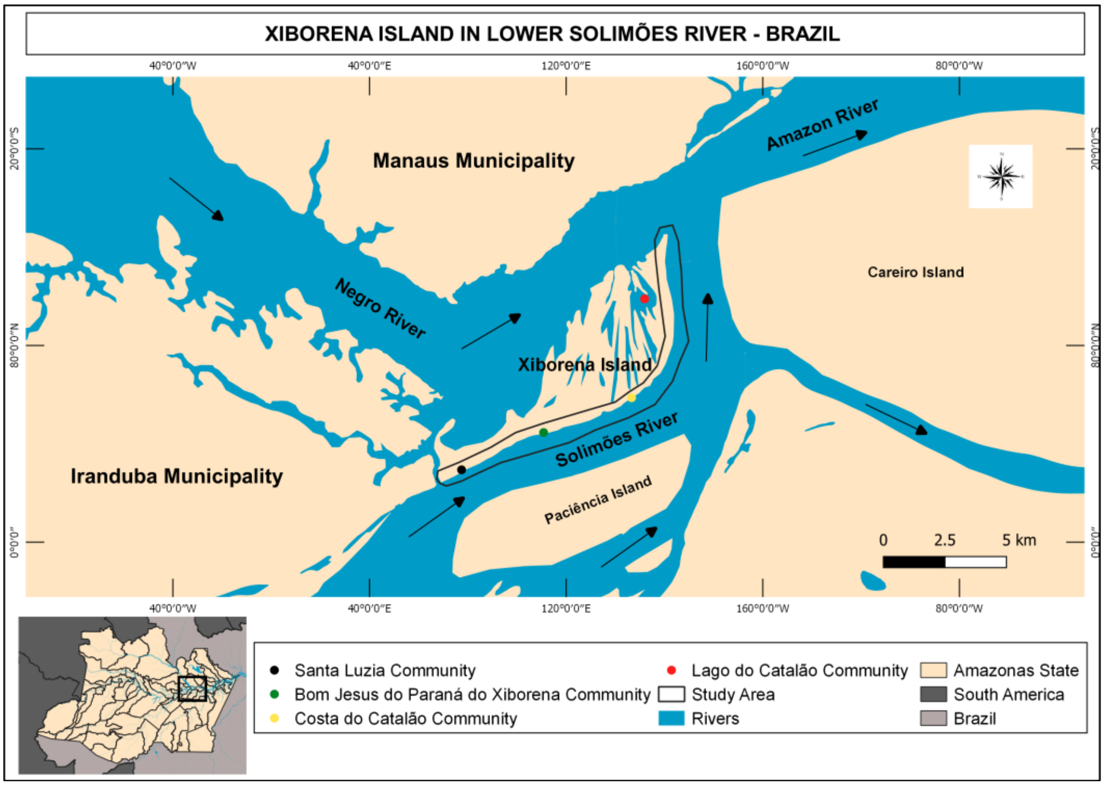
The hydrodynamic abrasion processes resulting from the chemical and physical action of water on banks and bed are not sufficient to explain the phenomenon of "*Terras Caídas*" in Amazon (CARVALHO, 2006). According to Igreja, Carvalho, Franzinelli (2010) the process occurs due to several factors that can act together: Hydrodynamics; Hydrostatic Pressure; Climate Factors (rainfall and wind); Lithology and Neotectonics; Anthropic Interference.

The Amazon River has its sources located in the Andes, characterizing it as a white water river (SIOLI, 1965), and is the largest river in the world in water discharge with 209,000 m³/s (MOLINIER *et al.*, 1996). In the Brazilian Amazon, after the border with Peru, the river is called Solimões, until the confluence with the Negro river in the region of the municipalities of Manaus and Iranduba, in Amazonas State. This work has the objective to understand the conditioning factors of phenomenon of the "*Terras Caídas*" in lower Solimões River - Brazil.

STUDY AREA LOCATION

Xiborena Island is located in the municipality of Iranduba - Amazonas, at the confluence of the Negro and Solimões rivers, the left bank of the Solimões river and the right bank of the Negro river. The area located on the Solimões River was defined as the study area. On the Xiborena Island there are four riverside rural communities, Santa Luzia, Bom Jesus do Paraná do Xiborena, Costa do Catalão (Solimões) and Lago do Catalão (Negro), the first three mentioned are within the research area (Figure 1).

Figure 1 - Study Area Location.



Arrows indicate flow direction. Org. - The Authors (2020).

METHODOLOGY

The processes involving the erosion of the banks in mega rivers are complex and dynamic, therefore the study area was monitored for two years (2017-2018) during the flood and ebb periods of the Solimões River to identify the main conditioning factors of “*Terras Caídas*”, hydrodynamic, hydrostatic, lithological and neotectonic, climatic (rainfall and wind) and anthropic factors were observed according to Carvalho (2006; 2012); Igreja, Carvallho and Franzinelli (2010) and Bandeira *et al.* (2018).

To complement the field data, secondary data from stations and satellites, obtained from the United States Geological Survey - USGS (https://earthexplorer.usgs.gov/) National Water Agency - ANA (http://www.ana.gov.br/) (Brazilian database) ; Ore-Hybam Project (http://www.ore-hybam.org/); National Meteorological Institute - INMET (http://www.inmet.gov.br/portal/) (Brazilian database); Brazilian Seismographic Network - RSBR (http://www.rsbr.gov.br/request.html) (Brazilian database) (Table 1):

Table 1 - Secondary data.

Variable	Period	Data Sets	Sources
Satellite Image	July – 1992	Landsat 5 and 8	USGS
	August – 2001		
	July – 2010		
	September - 2019		
Water Discharge	1973 - 2018	Manacapuru (14100000)	HYBAM
Flow Velocity	1984 - 2018	Manacapuru (14100000)	ANA
Suspended Sediment	1995 - 2014	Manacapuru (14100000)	HYBAM
	1984 - 2018		ANA
Water Level (Quota)	1973 - 2018	Manacapuru (14100000)	HYBAM
Rainfall	1984 - 2018	Manaus (82331)	INMET
Wild Direction	1960 - 1991	Manaus (82331)	INMET
Seismic Activity	2014-2018	Manacapuru (MACA)	RSBR

Org. - The Authors (2020).

Landsat 5 and 8 images with spatial resolution of 30 meters selected at 10-year intervals were used, opting for images with low cloud incidence. The images were preferably selected during the low water period to better obey the changes in the river forms (the only exception was the image of the year 2010 that corresponds to the end of the flood, this occurred due to the lack of better quality images for the area).

Erosion and deposition rates in the study area were calculated using overlapping images and during the period the area was monitored, the short-term evolution of the "*Terras Caídas*" was observed, using the position of houses, electricity poles as a parameter. and trees, according to the methodology proposed by Carvalho (2011) since, according to the author, the classic methodologies for measuring erosion evolution in river channels are difficult to apply to the "*Terras Caídas*" process. In order to map areas with predominance of erosion or deposition of the lower Solimões River, the works of Alves (2019) and Franzinelli (2011) were used, in addition to data from this work (2018).

The hydrodynamic factors analyzed were liquid discharge, flow velocity and suspended sediments and the monthly averages were calculated using the historical series data available for the station. According to Filizola and Guyot (2011) the ANA sediment data collection methodology is questioned by several authors, however the data are useful for multitemporal analyzes, so ANA data, in conjunction with HYBAM data, is used to understand the seasonal sedimentological dynamics of the lower Solimões River. For the calculation of suspended sediment load, it was considered that the sediment is transported at the same velocity as the flow in every cross section, being equal to the product of the water discharge by concentration (CARVALHO *et al.*, 2000; FILIZOLA; GUYOT, 2011), for this, Equation 1 was used:

$$Q_{ss} = 0{,}0864.Q.C \quad (1)$$

Q_{ss} is sediment load in ton/day. Q is water discharge in m³/s and C *is sediment* suspension concentration in mg/l. The constant refers to unit transformation factor.

The water level data were used to understand the ebb velocity of the Solimões River and how it influences the hydrostatic pressure in the lower Solimões River, according to Carvalho (2006; 2012). For the rainfall data, the monthly mean was calculated and for the wind direction data the data from the last climatological normal (1960-1991) were used. The data were used to understand the intensity that extreme events of precipitation and the waves formed by the action of the wind interfere in the “*Terras Caídas*” events", according to Carvalho (2006; 2012).

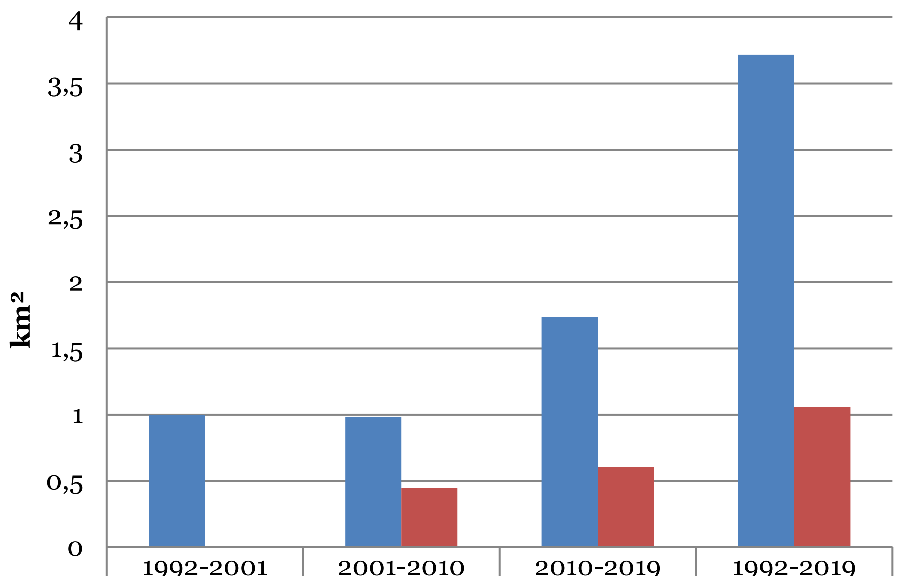
Despite the seismic data presenting a four-year historical series, it was decided to include the data in this work to understand the influence of neotectonics in “*Terras Caídas*” in a shorter time scale. A survey was also carried out in the specific literature of seismic events in the central Amazon region to understand the intensity of the events and how they can interfere in the “*Terras Caídas*” events. The lithology was analyzed to understand the susceptibility of the soil to erosion in the region.

RESULTS AND DISCUSSION

EROSION AND DEPOSITION OF SEDIMENTS IN STUDY AREA

Xiborena Island has convex riverbank, indicating that the depositional process predominated in the area (CHRISTOFOLLETI, 1981; CHARLTON, 2008; STEVAUX; LATRUBESSE, 2017). However, in recent years there has been an increase in area where erosive processes predominate (Figure 2). In Costa do Catalão community, between 2007 and 2009, the soils receded by approximately 200 m, causing loss of plantation, residences, roads, electricity poles and in upstream of community new sedimentary deposits are being used for cultivation and creation of animals by floating community Lago do Catalão. In recent years, erosion in the Costa do Catalão community area has resulted in a migration process that has wiped out the community.

Figure 2 - Erosion and deposition on Xiborena Island.

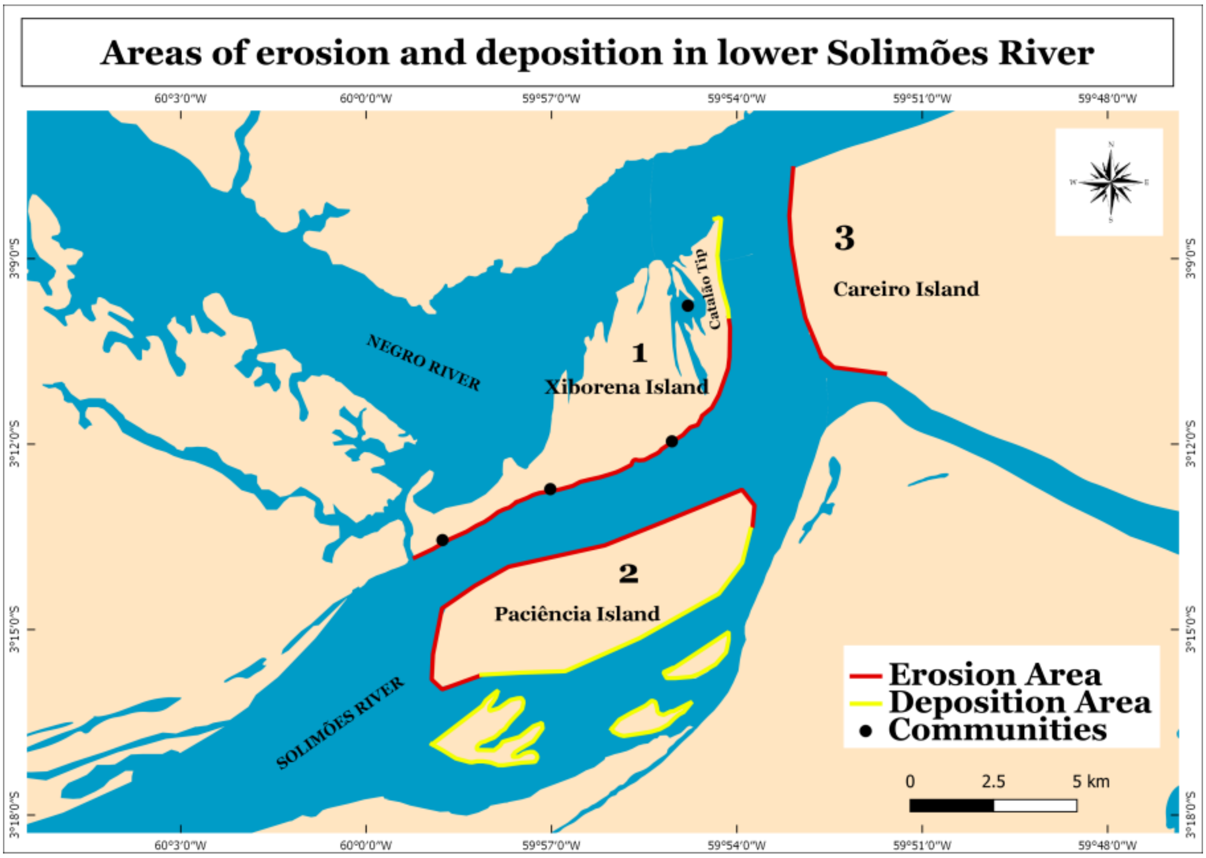


	1992-2001	2001-2010	2010-2019	1992-2019
Eroded	0,996	0,983	1,738	3,717
deposited	0,007	0,446	0,605	1,058

Source - The authors (2019).

It is observed that comparing the historical series from 1992-2001 and 2001-2010 there was a decrease in erosive processes (-1%) and an increase in depositional processes (6271%), with the 1992-2001 historical series showing the lowest rates of deposition. Between the 2001-2010 and 2010-2019 series, erosive processes increased by 71% and depositional 36%, indicating an increase in erosive processes in 2010-2019 series. However, sedimentary deposits between 2001-2019 are concentrated only at Catalão Tip (Figure 3).

Figure 3 - Areas of erosion and deposition in lower Solimões River.



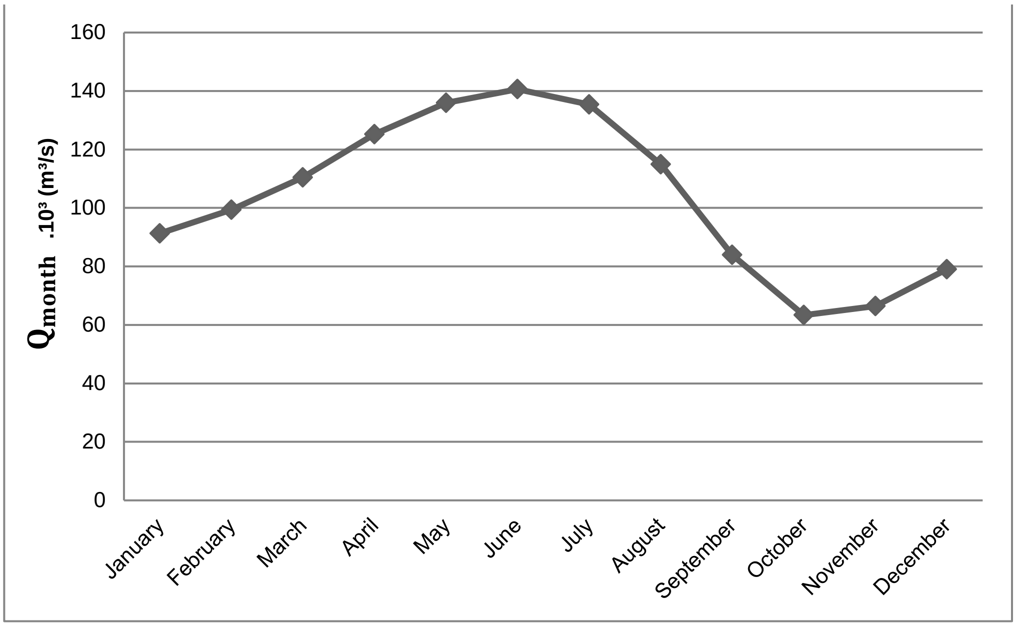
Source - 1: This work (2018). 2: Alves (2019). 3: Franzinelli (2011).

The morphology of the confluence channels has its own characteristics that can interfere in the erosion and sedimentation processes. At the confluence angle, in case of the confluence of the Negro and Solimões Rivers is 90° (FRANZINELLI, 2011), a zone of flow stagnation forms (BEST, 1987; BIRON; BEST; ROY, 1996; RHOADS; RILEY; MAYER, 2009), becoming a zone conducive to deposition of sediments due to the low flow velocity (HJUSLTROM, 1935). Sedimentation at Catalão Tip and erosion on Careiro Island can modify the morphology of mouth of Solimões River in some years (FRANZINELLI, 2011) and the worsening of deposition process on Paciência Island can increase the hydrodynamic pressure on the left bank of the lower Solimões, increasing the frequency and intensity of “*Terras Caídas*” process (ALVES, 2019).

HYDRODYNAMICS

Hydrodynamic is the main conditioning factor of "*Terras Caídas*", responsible for erosion and transport of sediments from banks of the Amazonian Mega Rivers (CARVALHO, 2006; 2012; IGREJA; CARVALHO; FRANZINELLI, 2010; BANDEIRA *et al.*, 2018). Among the hydrodynamic factors, hydraulic pressure, related to water discharge, is the most important factor to "*Terras Caídas*” (Figure 4) (CARVALHO, 2012).

Figure 4 - Water Discharge in Lower Solimões River.

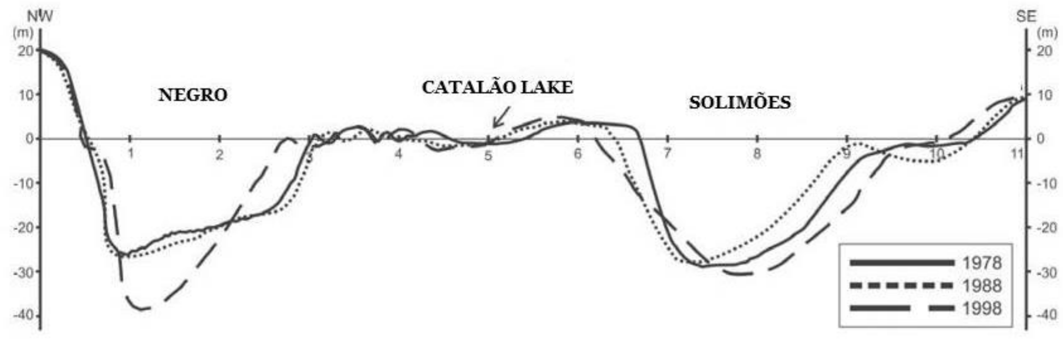


Source - Hybam. Org. - The Authors (2019).

The annual mean discharge to Manacapuru station, the last reference station of the Solimões River, is 103.855 m³/s. The month with the highest monthly mean discharge is June (140.616 m³/s), indicating that the peak discharge occurs in this month, and the month with the lowest discharge is October (63.344 m³/s), a variation of 77.272 m³/s is observed between the peaks of flood and ebb. At this point Solimões River is the largest river in mean annual discharge in the world (LATRUBESSE; STEVAUX, SINHA, 2005; LATRUBESSE *et al.,* 2005; LATRUBESSE, 2008).

The position of the river thalweg in the cross section influences the stability of the bank and the increase in hydraulic pressure in channel (CUNHA, 1995; NOVO, 2008; MARQUES, 2017). It is observed that in the study area the river thalweg is close to the left bank, even though there is variation in its location, depending on the reference year (Figure 5) (FRANZINELLI, 2011). Currently in the study area the thalweg is approximately 65 m from the left bank (ALVES, 2019).

Figure 5 - Cross-sectional profile of the Solimões and Negro Rivers.

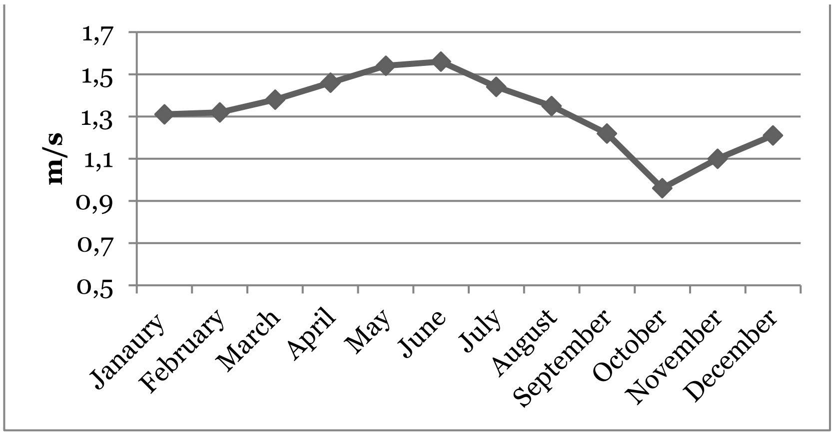


Source - Adapted from Franzinelli (2011).

Turbulence and flow velocity are closely linked to the river's work (CHRISTOFOLETTI, 1981). The "*Terras Caídas*" are associated with macro turbulence due to the large volume of water transported by river, the flow moves upward, vortexes and helical, with upward swirling flow the main cause of the "*Terras Caídas*" (STERNBERG, 1998; CARVALHO, 2012). The flow velocity (Hydraulic Power) (Figure

6) is important in removing particles from the riverbanks, the higher the velocity the greater the diameter of the eroded material (HJUSLTROM, 1935; 1939).

Figure 6 - Flow Velocity in Lower Solimões River.



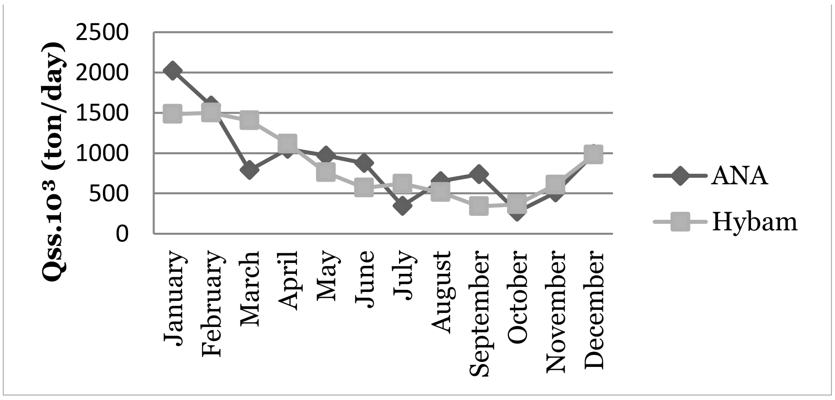
Source - ANA. Org. - The authors, 2019.

The month with the highest monthly mean of flow velocity is June (1,56 m/s) and the month with the lowest monthly mean is October (0,97 m/s), it is noted that the highest and lowest value correspond to discharge peaks in flood and ebb, respectively. However, the absolute velocity values vary from 2,5 m/s and 3 m/s, concentrating on the left bank (NASCIMENTO, 2016). The flow velocity in the study area has the power to erode silt, clay and sand (HJUSLTROM, 1935).

In left bank of lower Solimões River, the soil with silty texture predominates (MAGALHÃES, 2011), although silt is a material more resistant to erosion (MORISAWA, 1968), in “*Terras Caídas*” the predominance of silt decreases the stability of the bank, making it more conducive to erosive processes (FREITAS; ALBUQUERQUE, 2012).

Suspended sediments, in the case of hyperconcentrated flows, are an important factor for erosion in rivers (JIONGXIN, 1999). Analyzing the “*Terras Caídas*” Igreja, Carvalho and Franzinelli (2010) observed the importance of suspended load as a conditioning factor; however, few studies have investigated the real influence of suspended sediments on "*Terras Caídas*" events. At Manacapuru station the interannual sediment load is 383.10^6 ton/year, according to the HYBAM database (FILIZOLA; GUYOT, 2011), and ~ 400.10^6 ton/year, for the ANA database (FILIZOLA; GUYOT, 2009). It’s observed the values of Suspended Sediments (Qss) distributed monthly in Figure 7:

Figure 7 - Suspended Sediment in Lower Solimões River



Source - Hybam and ANA. Org. - The Authors (2019).

The sediments that the river carries in suspension reaches its peak between January, February and March, it is noted that the peak of suspended sediments at Manacapuru station occurs before the peak of water discharge, as observed by Filizola and Guyot (2011). In Hybam data the lowest value was found in September (340.493 ton/day), while the highest was in February (1.499.732 ton/day). ANA data indicate the lowest value in October (272.401 ton/day) and the highest in January (2.022.790 ton/day). It’s concluded that erosion influences the suspended sediments is more efficient during the flood period of the Solimões River and works in conjunction with hydraulic pressure and hydraulic power, causing basal erosion and disaggregating large volumes of sediments (sand, silt, clay) and vegetation into the flow (Figure 8 a, b, c).

Figure 8 a, b, c - “*Terras Caídas*” caused by hydrodynamics factors.

A) **B)**

C)

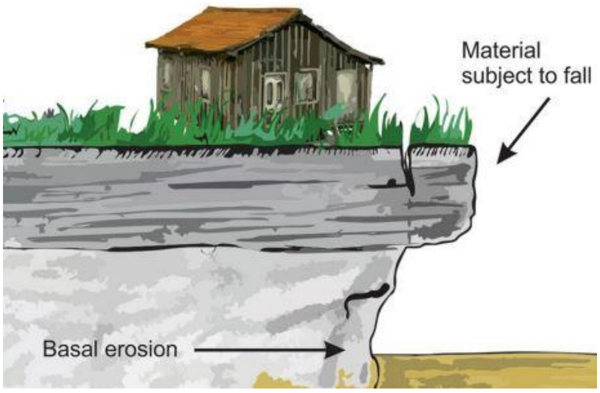


Figure 8a - Orthogonal fracture in riverbank caused by basal erosion, February 2018, water level: 1482 cm, in Costa do Catalão community. Figure 8b - Basal erosion and semicircular structure formed in the ebb flow, February 2018, water level: 1476 cm, in Santa Luzia community. Source - The authors (2018). Figure 8c - Schematic displaying the undermining process during dry flow and part of flood flow. Source - Bandeira *et al.* (2018).

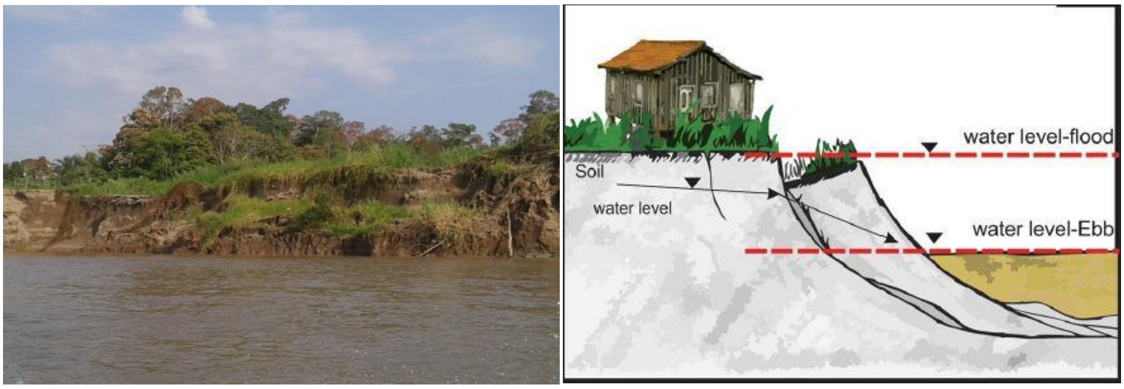
Hydrostatic Pressure

Hydrostatics is the term that is commonly used in the technical literature to describe the behavior of fluids, particularly fluids at rest. Unlike fluid in motion, a fluid at rest in relation to its limits tends to be in a state of shear stress is zero, thus the pressure imposed on point of fluid mass at rest is transmitted in all directions without reduction (KINDSVATER, 1958). On riverbanks, this process occurs due to the rapid lowering of the water level; therefore, drop in the level of the piezometric surface will not follow of river level (quota). (GUIDICINI; NIEBLE, 1983; TERZAGHI, 1950).

Hydrostatic pressure is an important conditioning factor for “*Terras Caídas*” in the Amazon (TRICART, 1977). The *ribeirinhos* (Riverside People) classify, in a generic way, the resulting process as land collapse (CARVALHO, 2012; BANDEIRA *et al.*, 2018). The water that covers the floodplain during the flood, leaving it completely covered for approximately three months (May, June, July), allowing water to infiltrate the soil. The pressure exerted by the water in the soil occurs during the ebb, causing sliding on riverbank (Figure 9 a, b) (ALVES, 2013; STERNBERG, 1998). During the ebb, semicircular structures are formed at the riverbank, influenced by hydrostatic pressure, which during the flood are saturated with water (see figure 8) (TRICART, 1977).

Figure 9 a, b - "Terras Caídas" caused by hydrostatic pressure.

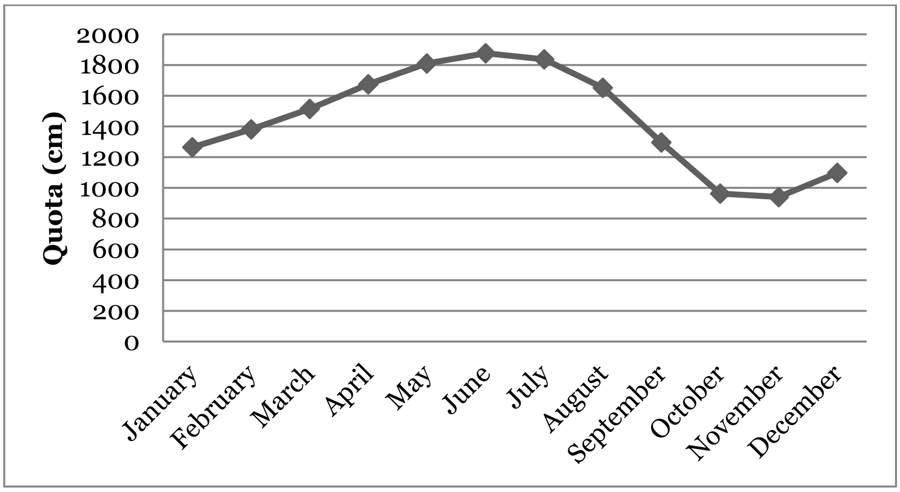
A) **B)**



Figures 9a: Riverbank Slide, August 2017, water level: 1723 cm, Bom Jesus do Paraná do Xiborena community. Source: The authors (2017). Figure 9b: Illustrative profile exhibiting the basic geomechanical model of sliding hazards in riverbanks. Source - Bandeira *et al.* (2018).

The Manacapuru Station indicates that between the months of January and April the river level rises, reaching the peak of flooding in June. The level of the river begins to descend from the second half of July, beginning to ebb (Figure 10). The piezometric level in lower Solimões River begins to rise in May and to descend in July/August, but in a delayed manner at level of Solimões River (MAGALHÃES, 2011; MAGALHÃES; VIEIRA, 2018).

Figure 10 - Water Level (Quota) in Lower Solimões River.



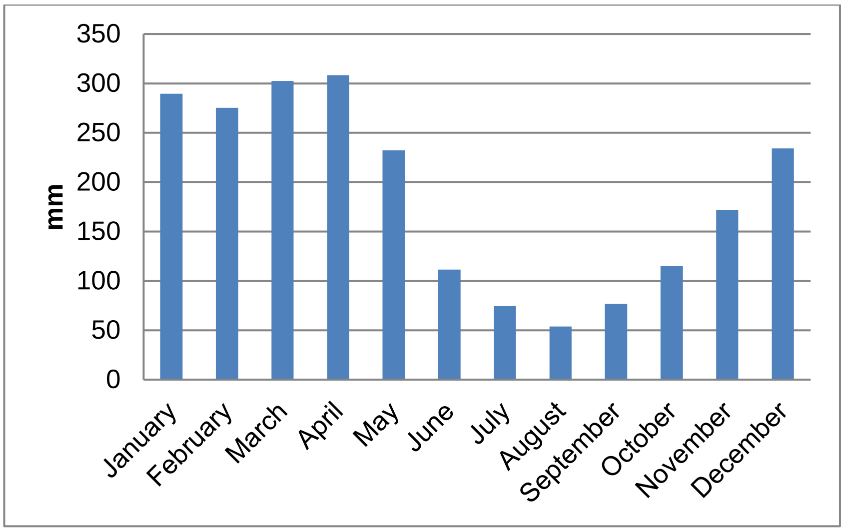
Source - Hybam. Org. - The Authors (2019).

In 2017, in the second half of July, the river level dropped 84 cm, in August 440 cm and in September 547 cm, 322 cm only in the first half of month. In 2018, in second half of July, the river level dropped 57 cm, in August 212 cm and in September 353 cm. It is observed that in the year 2017 the Solimões River level dropped faster, indicating greater influence of hydrostatic pressure in the study area, during the monitoring period, this year.

RAINFALL AND WIND

The mean annual rainfall at the Manaus station is 2245.4 mm/year. The months with the highest rainfall are January, February, March, April and May (Figure 11), with the rainy season occurring between December and May. When there are large volumes of precipitation in a short time, the soil saturated due to porosity and permeability, making terraces and floodplains heavy, conditioning the mass movement. According to Carvalho (2006; 2016), “*Terras Caídas*” events occur more frequently when there is an increase in precipitation and hydrodynamic pressure.

Figure 11 - Rainfall at Manaus Station.



Source - INMET. Org. - The Authors (2019).

In large rivers, the abrasive action of waves driven by winds can cause undermining of banks (MEIS, 1968; THORNE, 1991; KOTOKY, 2005; CARVALHO, 2006; 2012), and in wide channels, as is the case of lower Solimões River, the wind speed increases, intensifying the waves, however there are still no detailed studies on the frequency and magnitude of the waves and their influence on erosion processes (BANDEIRA *et al.,* 2018). The wind direction in study area is predominantly NE, except for August and September (SE) (Table 2), indicating that the waves formed by the winds may affect the study area on a smaller scale. During storms, this process occurs with greater intensity.

Table 2 - monthly mean wind direction.

Month	Wind Direction
January	NE
February	NE
March	NE
April	NE
May	NE
June	NE
July	NE
August	SE
September	SE
October	NE
November	NE
December	NE

Source - INMET. Org. - The Authors (2019).

LITHOLOGY AND NEOTECTONICS

The lithology of the lower Solimões floodplain is composed of holocenic alluvial deposits (LATRUBESSE; FRANZINELLI, 2002), and fluvic neossol predominating in the area of left bank of lower Solimões River (MAGALHÃES; GOMES, 2013), indicating soil with low stability and susceptible to erosive processes and mass movement.

Neotectonics "has been responsible for the events of larger "*Terras Caídas*", especially along the rivers…” (IGREJA; CARVALHO; FRANZINELLI, 2010, p. 139). The confluence of the Negro and Solimões rivers is located in the transcurrent neotectonic strip that covers the entire Central Amazon (IGREJA, 1998), occurring intersections of the N40E and N65W structural directions and interfering in the holocenic syntectonic deposits on Xiborena Island (FRANZINELLI, 2011). The reactivation of syntectonic deposits can condition events of "*Terras Caídas*" (IGREJA, CARVALHO; FRANZINELLI, 2010).

Manaus is considered a seismogenic zone with epicenters located around the confluence between the Negro and Solimões rivers (COSTA *et al.*, 1996; MIOTO, 1993). Downstream of the study area, an earthquake with an estimated magnitude of ~7 was recorded in 1690, being considered the largest in the Amazon region, afterwards earthquakes were recorded in the region of the municipality of Codajás in 1963, upstream of the study area, with magnitude of 5.1, result of a reverse fault oriented NNE; and in the municipality of Manaus in 1980, with magnitude 3.4, the result of a reverse fault oriented approximately to NNW, probably the tremors of these events affected the study area (ASSUMPÇÃO; SUÁREZ, 1988; VELOSO, 2014). However, at Manacapuru station (MACA) in 2014-2020 historical series there are no seismic records, indicating that, in recent years, when the events of “*Terras Caídas*” have intensified, this has not been a conditioning factor for Xiborena Island.

ANTHROPIC INTERFERENCE

The human interference is a determinant of “*Terras Caídas*”, occurring to a lesser extent (BANDEIRA *et al.*; CARVALHO, 2012). In study area there are three rural communities (Costa do Catalão, Santa Luzia and Bom Jesus do Paraná do Xiborena), which promoted the removal of riparian forest for planting short-cycle agricultural crops and pastures for animals. Sternberg (1998) considers that removal of vegetation has little effect on increasing the intensity of the process, however the presence of vegetation influences the infiltration speed and the variation of the piezometric level, so that erosion occurs slowly (mainly the hydrostatic pressure) (COSTA *et al.,* 1996; SUTILI, 2007; BANDEIRA *et al.,* 2018).

Boat action that promotes waves that contribute to basal erosion, which may cause “*Terras Caídas*”, with the speed of the boats being the main factor in the formation of waves and the intensity of the impact with the riverbanks (CARVALHO, 2006; 2012; QUEIROZ; SOARES; TOMAZ NETO, 2018; BANDEIRA *et al.*, 2018). Currently, river locomotion is the main means of transport in the Amazon, with boats that can reach speeds above 50 km/h.

FINAL CONSIDERATIONS

In last ten years (2010-2019) the area of eroded sediments has increased by 71% and although the area of deposited sediments has increased this has only occurred in Catalão Tip. The factors that influenced “*Terras Caídas*” in lower Solimões River are mainly hydrodynamics, hydrostatic pressure, rainfall and wind; lithology, neotectonics and anthropic influence occur on a smaller scale.

The hydrodynamic factors and the rain influence the “*Terras Caídas*” more intensely during the river flood, the processes influenced by the wind direction occur throughout the hydrological year, but with greater intensity during storms. Hydrostatic pressure occurs more frequently in the ebb causing landslides. The lithology influences the stability of the riverbanks due to unconsolidated sediments, providing erosion and mass movements. It is observed that, despite being present in the region, neotectonics was not important in increasing the intensity of the "*Terras Caídas*" in the study area in recent years. Human activity influences destroying riparian forests and the basal erosion caused by waves formed by boats in the region.

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