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Congo River: Analysis of suspended sediment flux in a multichannel megasystem in Central Africa

Rio Congo: Análise do fluxo de sedimentos suspensos em um megassistema multicanal na África Central

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Abstract

Tropical mega rivers play a crucial role in transferring water and sediment to the oceans. The Congo River is the second largest in the world by volume of water, playing a significant role in the export of fresh water and sediment from the continent to the Atlantic Ocean. This paper aims to analyze the variability of the suspended sediment flux of the Congo River between 2005 and 2018. Suspended Sediment Concentration (SSC), water discharge and water level data were used at the Brazzaville station, which represents 97% of the basin area, and precipitation data for the entire basin. Solid discharge, specific sediment yield and denudation rate of the basin were estimated. The estimated water discharge was 41 268 $m^3.s^{-1}$ for the period between 1947 and 2023, with a bimodal river regime with a flood peak in December and a secondary peak in May. The mean annual SSC estimated for the Congo River was 27.20 $mg.L^{-1}$. A moderate ($r = 0.48$) and weak ($r = -0.26$) correlation was observed between SSC and precipitation, and SSC and water level, respectively, possibly influenced by the basin's terrain characteristics. During the year, the Congo River transfers 33.66×10^6 $ton.year^{-1}$ of sediment to the ocean, has a specific sediment yield of 9.62 $ton.km^{-2}.year^{-1}$ and a very low denudation rate (3.37 $mm.ky^{-1}$).

Keywords:
Suspended Sediment Concentration, Mega Rivers, Tropical Rivers.

Resumo

Os mega rios tropicais desempenham um papel crucial na transferência de água e sedimento para os oceanos. O rio Congo é o segundo maior do mundo em volume de água, desempenhando um papel significativo na exportação de água doce e sedimentos do continente para o Oceano Atlântico. Este artigo tem como objetivo analisar a variabilidade do fluxo de sedimentos suspensos do rio Congo no período entre 2005 e 2018. Foram utilizados dados da Concentração de Sedimentos Suspensos (CSS), descarga líquida e nível da água na estação de Brazzaville, que representa 97% da área da bacia, e dados de precipitação para toda a bacia. Foram estimadas a descarga sólida, produção específica de sedimentos e a taxa de denudação da bacia. A descarga líquida estimada foi

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41 268 $m^3.s^{-1}$ para o período entre 1947 e 2023, com um regime fluvial do tipo bimodal, com pico de cheia no mês de dezembro e um pico secundário em maio. A média anual da CSS estimada para o rio Congo foi 27,20 $mg.L^{-1}$. Foi observada uma correlação moderada (r = 0,48) e fraca (r = -0,26) entre a CSS e a precipitação, e a CSS e o nível da água, respectivamente, possivelmente influenciada pelas características do terreno da bacia. Durante o ano, o rio Congo transfere para o oceano 33,66 × 10^6 $ton.ano^{-1}$ de sedimentos, possui uma produção específica de sedimentos de 9,62 $ton.km^{-2}.ano^{-1}$ e uma taxa de denudação muito baixa (3,37 $mm.ky^{-1}$).
Palavras-chave:
Concentração de Sedimentos Suspensos, Mega Rios, Rios Tropicais.

I. INTRODUCTION

Large tropical rivers play a crucial role in transferring water and sediment to the oceans, significantly influencing the global hydrological cycle and climate (HARDING et al., 2011; LI et al., 2020). Climate changes significantly affect the hydrosedimentary dynamics of rivers, making them increasingly sensitive to morphodynamic changes (HADDELAND et al., 2014). Therefore, understanding the current dynamics of suspended sediment transport is vital for accurately assessing the impacts of climate change on fluvial channels.

Sediment flux to the ocean is a key factor in the global geochemical cycle (WALLING; FANG, 2003; LI et al., 2020). It also plays a crucial role in analyzing erosion processes and the global denudation rate of continents (WALLING, 1987; ANDUALEM et al., 2023). Both terrestrial (intra-basin) and marine ecosystems are directly influenced by the availability of water and sediment (DOLL et al., 2009), as well as by human activities (KETTNER et al., 2010; BIEMANS et al., 2011; QUEIROZ et al., 2018). Approximately 43% of the total dissolved carbon flux from land to oceans is transported by fluvial channels (LUDWIG et al., 1996). Thus, large river systems are essential for maintaining aquatic and terrestrial ecosystems and supporting human activities such as agriculture and energy generation.

Most mega rivers, defined by a mean annual water discharge exceeding 17 000 $m^3.s^{-1}$, exhibit an anabranching channel pattern (LATRUBESSE, 2008). These rivers show stable islands and multiple channels (multichannel), as described by Brice (1984) and Leli (2015). Examples include the Brahmaputra and Yangtze rivers in Asia, the Congo in Africa, and major rivers in South America such as the Amazon, Orinoco, Paraná, Negro, and Madeira. This channel pattern is observed across various climate zones and geological or geomorphological settings (LATRUBESSE, 2008).

Due to their substantial water volume, mega rivers play a significant role in transporting solid discharge to the oceans. However, studies on the processes that control suspended sediment transport from mega rivers

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to the ocean remain limited. The large size of these river basins presents challenges in accurately quantifying these processes across spatial and temporal scales (MOLLIEX et al., 2019). The multi-causal processes that control sediment production—such as channel slope, precipitation, temperature, vegetation, and soil texture—vary spatially across the basin, making measurement difficult (PELLETIER, 2012). The Congo River, located in Central Africa, is the second-largest river by water discharge in the world and plays a fundamental role in the marine and terrestrial ecosystems of the tropical region. Therefore, analyzing the current hydrosedimentary dynamics of this river is decisive to understanding how environmental changes and human activities, such as deforestation, mining, and dam construction, impact sediment transport processes and freshwater supply to the ocean.

This paper aims to analyze and characterize the historical variability of Suspended Sediment Concentration (SSC) from 2005 to 2018 in the Congo River, Central Africa. The results offer an updated contribution to knowledge on this topic, by complementing previous work. This enhances the field of study and provides a solid basis for future investigations.

II. PHYSIOGRAPHY OF THE CONGO BASIN

The Congo River basin (Figure 1) is the second largest on the planet in terms of area, covering 3 700 000 km². The Congo River, with a length of 4 374 km, is the second longest river in Africa after the Nile (DEVROEY, 1951) and the second largest in the world in terms of water volume, with a water discharge of approximately 40 000 $m^3.s^{-1}$ (LATUBRESSE, 2008). The river forms extensive archipelagos within its channel, defining it as a highly complex anabranching system (O'LOUGHLIN et al., 2013; STEVAUX; LATRUBESSE, 2017). This basin drains several countries: the Democratic Republic of the Congo, Angola, Zambia, Tanzania, Burundi, Central African Republic, Cameroon, and Republic of the Congo (RUNGE, 2007). The Congo River's unique drainage characteristics include crossing the equator twice and covering approximately 25% of the humid tropical area, contributing around 3.4% of the total freshwater input into the Atlantic Ocean (PROBST; TARDY, 1987).

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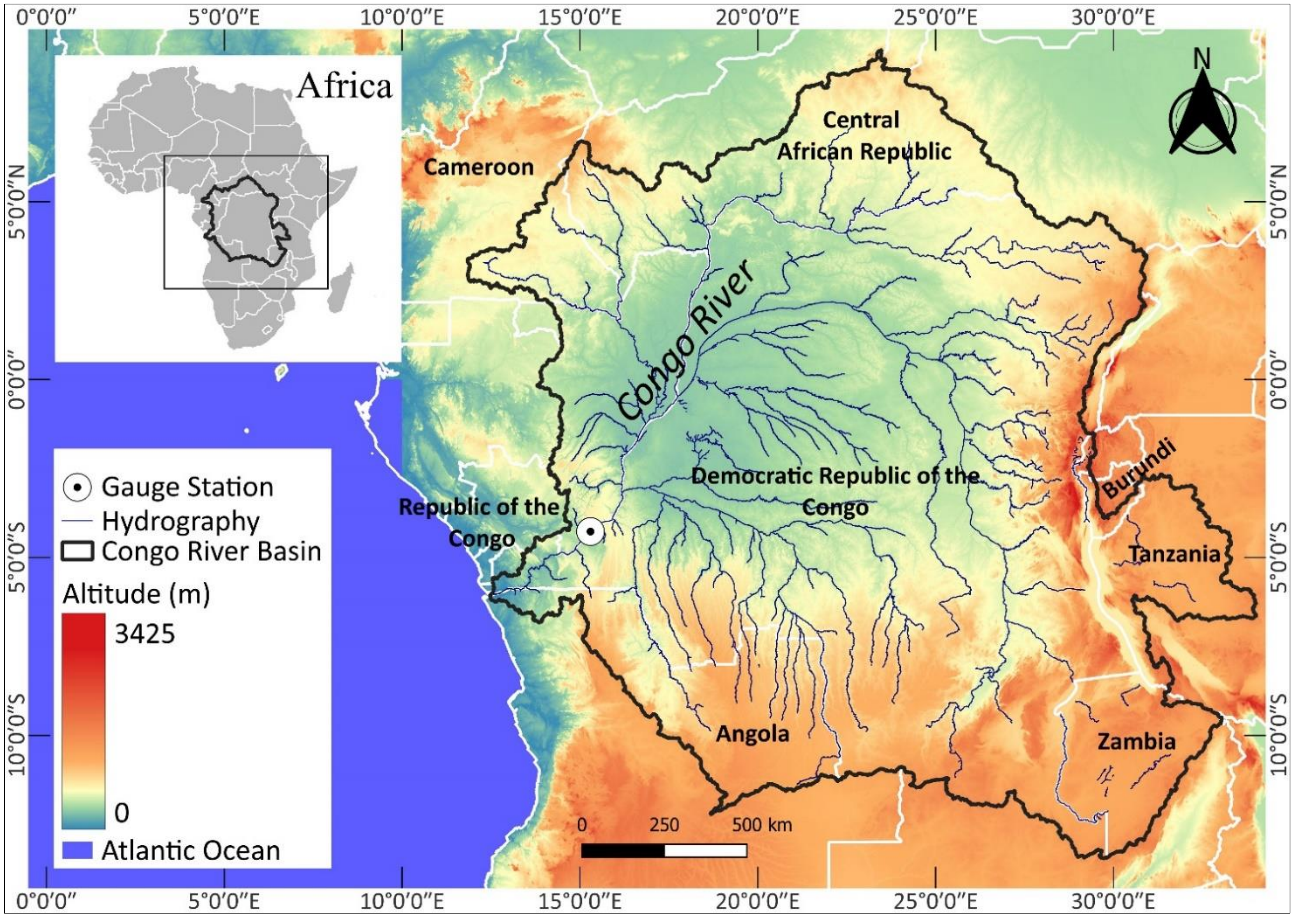

Figure 1 - Location map, hydrography and altimetry, Congo River basin, Central Africa.
Source: This Work, 2024.

The Congo Basin is geologically characterized by a Precambrian basement (Congo Shield) (Figure 2), which includes Archean cratonic blocks and numerous Paleozoic and Neoproterozoic mobile belts (WIT; LINOL, 2014). These rocks are deeply weathered (RUNGE, 2007) and have a geological history of 3.8 billion years, with some rocks along the northeastern edge possibly as old as 4.0 billion years (WIT; LINOL, 2014). Paleozoic and Neoproterozoic sediments outcrop on the basin's periphery (KADIMA et al., 2011). The central area of the basin, known as the Cuvette Centrale, has low altitudes (between 300 and 500 meters) and drains unconsolidated Cenozoic sediments (RUNGE, 2007).

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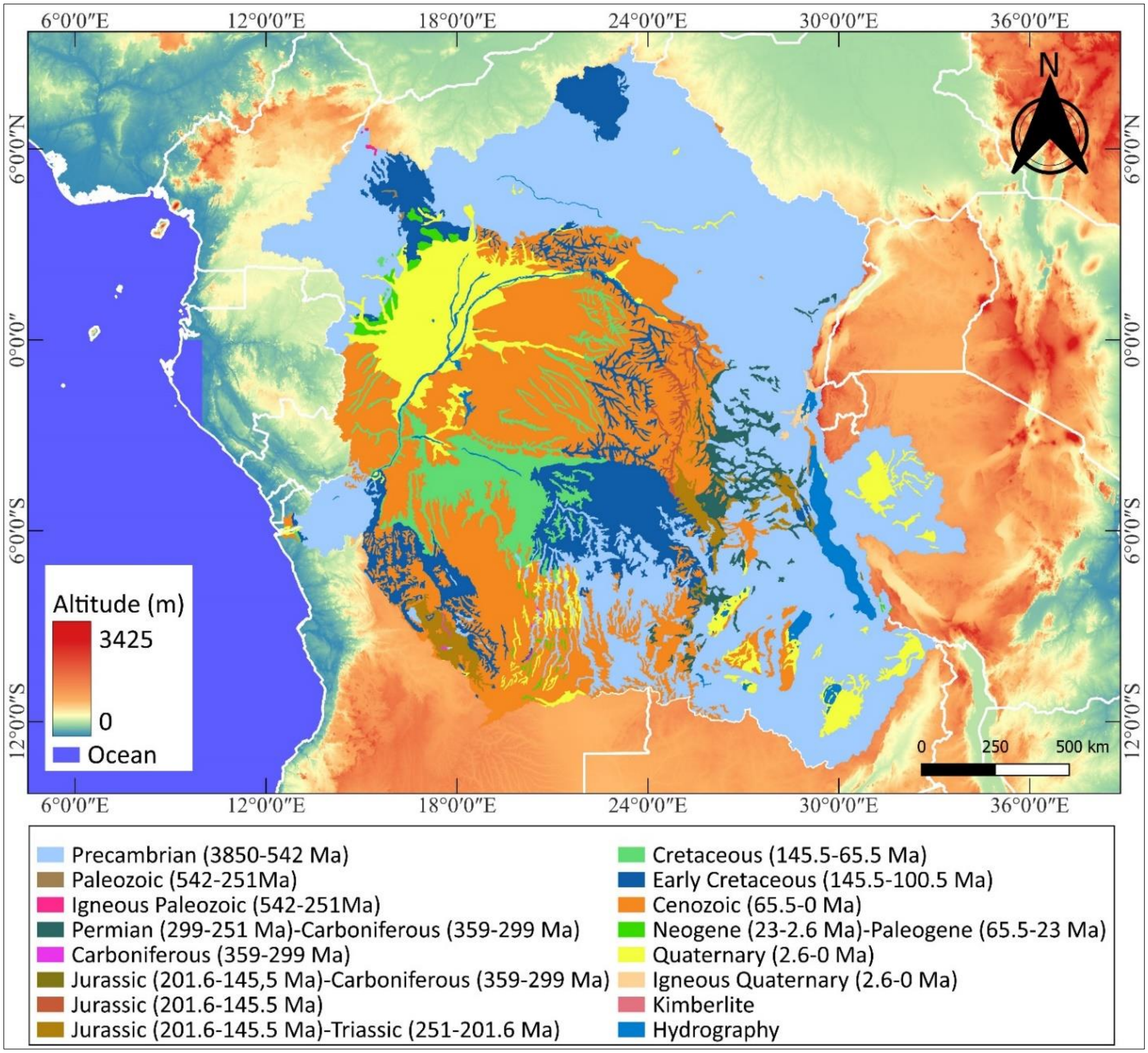

Figure 2 - Lithological map of the Congo River Basin, Central Africa.
Source: Adapted from United States Geological Survey, 2002.

The climate of the Congo River basin is predominantly tropical, hot, and humid (FLUGEL et al., 2015). There are three main climatic zones: (I) in the central area (both hemispheres), the climate is humid equatorial; (II) at higher latitudes, it is humid tropical with a monsoon season; and (III) at the northern and southern limits, it is semi-arid tropical with a dry season (KOTTEK et al., 2006).

The basin is surrounded by rounded hills of deeply weathered Precambrian and Mesozoic formations in a savannah vegetation (RUNGE, 2007). Less than 44% of the basin is covered by tropical vegetation (LARAQUE et al., 2020). The Cuvette Centrale is flooded during the rainy season and almost waterless during the dry season, serving as a significant sediment deposition area (LARAQUE et al., 1998; MOLLIEX et al., 2019). This region forms a large area of flooded vegetation in the middle Congo River (KITAMBO et al., 2022; PARIS et al., 2022).

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The sediments and soils of the Congo basin are influenced by tectonic shifts (DALY et al., 1991, 1992). The seismic activity within the basin indicates that the crystalline basement does not behave entirely like a rigid cratonic mass (AYELE, 2002; DELVAUX; BARTH, 2010). Significant changes in the Congo River's drainage pattern occurred at the end of the Cenozoic and during the Neogene periods, driven by structural controls, tectonics, and active fluvial processes (FLUGEL et al., 2015).

According to Flugel et al. (2015), the evolution of the Congo Basin during the Cenozoic can be described by two models: (I) a gradual shift from the depocenter of the Ogoué and Cuanza rivers towards the Congo River, attributed to the capture of the Congo endorheic basin at the end of the Cenozoic (BABONNEAU et al., 2002; ANKA et al., 2009), and (II) a southward migration of the Congo River system's drainage network from the Cretaceous to the Cenozoic (KARNER; DRISCOLL, 1999; NIBBELINK; BUDIHARDJO, 2002). During the Neogene, particularly in the early and middle Miocene epochs, significant reorganizations occurred in the central Congo Basin's drainage patterns, which was draining south at that time. In the Late Neogene, the water flow stabilized through the lower rapids of the Congo River, establishing a connection to the Atlantic Ocean. The current morphology of the channel, characterized by drainage crossing the equator twice, was fully established only in the Quaternary (Pleistocene) (FLUGEL et al., 2015).

III. MATERIALS AND METHODS

We used data on water discharge and water levels from 1947 to 2023, and Suspended Sediment Concentration (SSC) data from 2005 to 2018, obtained from the Brazzaville station (code = 50800000) provided by SO-HYBAM (https://hybam.obs-mip.fr/). SO-HYBAM's protocol adheres to the recommendations of the UNEP GEMS/Water Program (CHAPMAN, 1992), with surface sampling is conducted every 10 days. The station, located about 500 km from the river's mouth, collects runoff information from 97% of the Congo River basin, encompassing a drainage area of 3 700 000 km². Calculations included solid discharge (Equation 1), annual solid discharge (Equation 2), and specific sediment yield (Equation 3) of the Congo River.

$$Q_s = Q \times SSC \times 0.0864 \quad (1)$$

Where: Qs is the solid discharge (in ton.day^{-1}). Q is the water discharge (in m^3.s^{-1}) observed at the Brazzaville station. SSC is the suspended sediment concentration (mg.L^{-1}). The constant 0.0864 is a conversion factor to the unit ton.day^{-1}.

$$Q_{sa} = Q_s \times 365 \quad (2)$$

Where: Qsa is the mean annual solid discharge (in ton.year^{-1}).

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$$Q_{sp} = \frac{Q_{sa}}{A_b} \quad (3)$$

Where: Qsp is the specific sediment yield. Ab is the drainage area of the Brazzaville station.

The denudation rate of the Congo River basin was estimated based on the annual solid discharge (Qsa), converted into the volume of material removed using the ratio between Qsa and the density of rock or soil. The density value utilized was proposed by Wittmann et al. (2011). The denudation rate was calculated using Equation 4:

$$L = \left(\frac{V}{A_b}\right)1000 \quad (4)$$

Where: L is the denudation rate ($mm.year^{-1}$), to obtain the value in $mm.ky^{-1}$ multiply the result by 1000. V is the volume of material removed ($m^3.year^{-1}$). A_b is the area of the basin (m^2).

Historical precipitation data were estimated using the CHIRPS v.2 project (https://www.chc.ucsb.edu/data/chpclim), which provides climatological data and spatializes precipitation patterns for regions with sparse conventional station coverage, such as the Congo River basin. The historical dataset analyzed spans from 2005 to 2018, aligning with the period of SSC data, and covers the entire Congo River basin. SSC, water level, water discharge, and precipitation data were evaluated using the coefficient of determination (R^2) and Pearson's correlation coefficient (r).

IV. Results and Discussion

The water level regime of the Congo River exhibits distinct seasonal variations throughout the year. It is characterized by a bimodal pattern with two notable peaks: a major flood peak in December and a secondary peak in May. From January to March, water levels significantly decrease following the December peak. In April and May, water levels rise slightly, followed by another decline in June. The lowest water levels are typically recorded in August. From September onwards, water levels gradual increase, culminating in the peak flood in December. The mean annual water discharge for the period between 1947 and 2023 was estimated at 41 268 $m^3.s^{-1}$. The highest discharge occurs in December (56 959 $m^3.s^{-1}$) and the lowest in August (31 827 $m^3.s^{-1}$), with a range of 25 132 $m^3.s^{-1}$ (Figure 3). The discharge regime of the Congo River is relatively stable, with low ratio between maximum and minimum discharge (Qmax/Qmin = 1.79) and maximum and mean discharge (Qmax/Qmean = 1.38).

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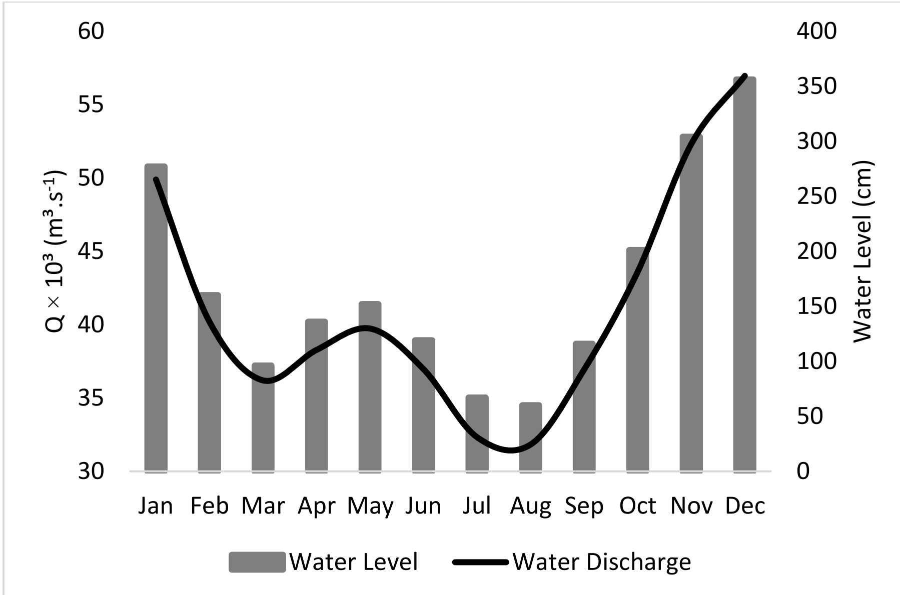

Figure 3 - Water discharge and water level, Brazzaville station, between 1947 and 2023, Congo River, Central Africa.
Source: This Work, 2024.

Annual precipitation in the Congo River basin is 1 513 $mm.year^{-1}$. The region experiences a well-defined dry period between June and July, with mean precipitation of 72.33 $mm.month^{-1}$. The highest rainfall occurs in October (178.98 $mm.month^{-1}$), while the lowest is in June (71.99 $mm.month^{-1}$). The wettest months are between October and April, with an average of 149.46 $mm.month^{-1}$ (Figure 4). The coefficient of determination (R^2) between water level data and precipitation for the period between 2004 and 2018 is low ($R^2 = 0.24$).

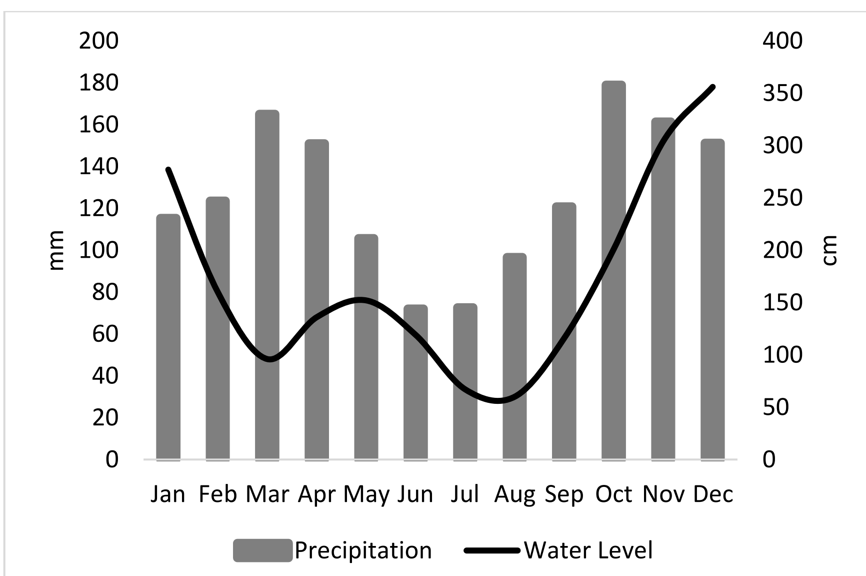

Figure 4 - Water level x precipitation, between 2005 and 2018, Congo River basin, Central Africa.
Source: This Work, 2024.

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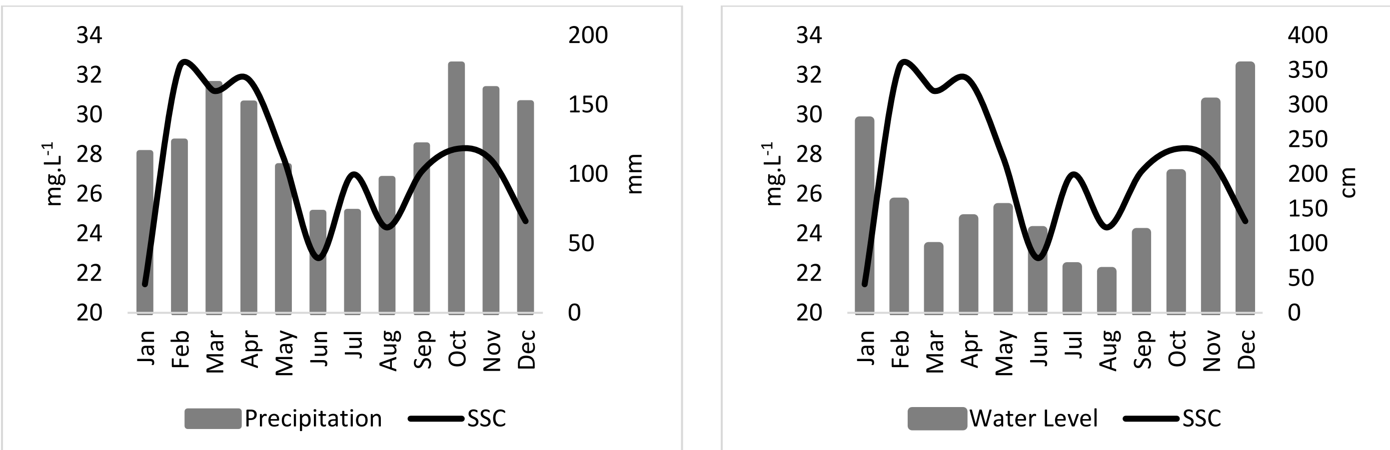
The mean annual Suspended Sediment Concentration (SSC) for the Congo River between 2005 and 2018 was estimated at 27.20 $mg.L^{-1}$. The highest concentrations occur between February (32.40 $mg.L^{-1}$) and April (31.78 $mg.L^{-1}$), with the lowest in January (21.44 $mg.L^{-1}$) (Figure 5). The range was 10.96 $mg.L^{-1}$, the standard deviation was 9.22, and the coefficient of variation was 33%. No clear pattern in sediment distribution was observed throughout the hydrological year, as the months with the highest and lowest concentrations are consecutive (February and January). The coefficients of determination between SSC and water level data (R^2 = 0.19) and SSC and precipitation (R^2 = 0.22) were low for both variables (Figures 5a, 5b).



a) b)

Figure 5 - SSC x Water Level (5a) and SSC x Precipitation (5b), between 2005 and 2018, Congo River, Central Africa.
Source: This Work, 2024.

The mean monthly solid discharge (Qs) of the Congo River was estimated at 92 222 $ton.day^{-1}$. December had the highest contribution (117 824 $ton.day^{-1}$) and August the lowest (62 105 $ton.day^{-1}$), with a range of 55 718 $ton.day^{-1}$. The relationship between Qs data and water discharge showed a moderate to good R^2 of 0.66 (Figure 6). The annual solid discharge (Qsa) is 33.66 × 10^6 $ton.year^{-1}$, and the specific sediment yield (Qsp) is 9.62 $ton.km^{-2}.year^{-1}$. The denudation rate of the Congo River basin was estimated at 0.00337 $ton.year^{-1}$ or 3.37 $mm.ky^{-1}$.

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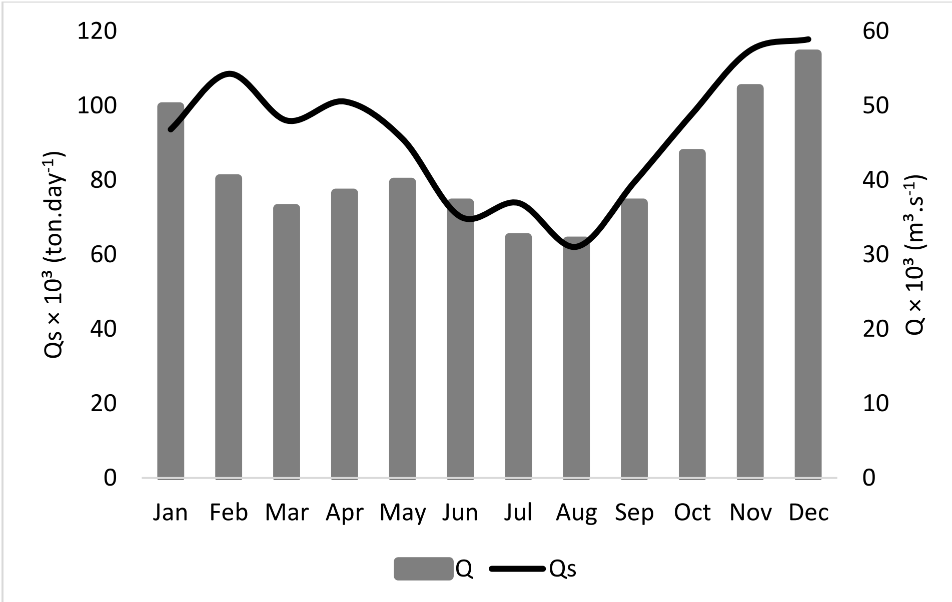

Figure 6 - Solid discharge (Qs), between 2005 and 2018, Congo River, Central Africa.
Source: This Work, 2024.

Figure 7 illustrates the Pearson linear correlation between variables Q (water discharge), SSC (suspended sediment concentration), Qs (solid discharge), water level at Brazzaville, and precipitation (rainfall for the basin). Positive correlations are indicated by right-oriented figures, while left-oriented figures denote negative correlations.

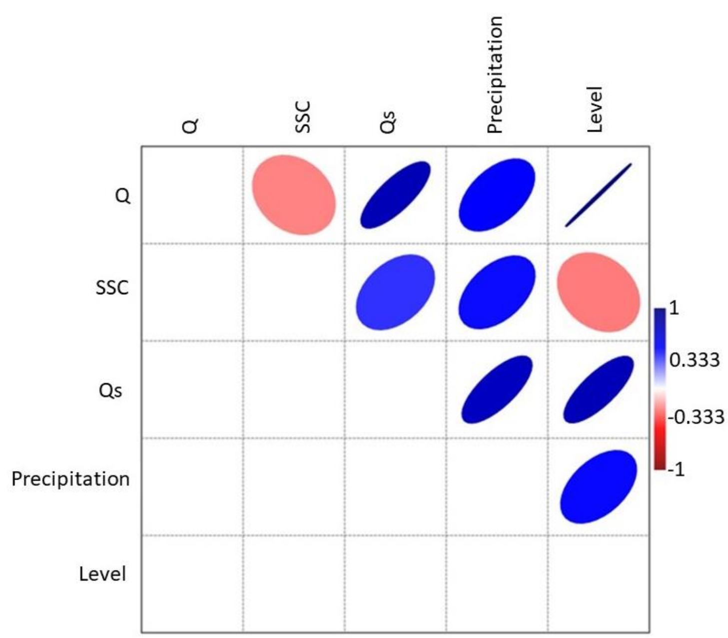

Figure 7 - Correlogram between the mean monthly data for water discharge (Q), suspended sediment concentration (SSC), solid discharge (Qs), precipitation and water level.
Source: This Work, 2024.

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The correlation coefficient between Q and SSC is -0.24, indicating a weak negative relationship. This suggests that an increase in water discharge slightly reduces suspended sediment concentration. Conversely, the correlation coefficient between Q and Qs is 0.78, indicating a strong positive relationship. This implies that as water discharge increases, solid discharge also increases. This relationship can be attributed to the fact that higher water discharge facilitates greater transport of suspended sediment. Among the variables analyzed, water discharge best explains the average monthly variability of SSC.

The correlation coefficient between SSC and precipitation is 0.48, suggesting a moderate positive relationship where increased precipitation leads to higher suspended sediment concentration. The correlation coefficient between SSC and water level is -0.26, indicating a weak negative relationship; as river levels rise, suspended sediment concentration tends to decrease.

The Congo River at Brazzaville exhibits low water discharge variability (Qmax/Qmin = 1.79) and a low flood regime (Qmax/Qmean = 1.38). This dynamic is similar to the Amazon River at Óbidos (Qmax/Qmin = 2.28 and Qmax/Qmean = 1.36). However, other large tropical rivers such as the Orinoco (Qmax/Qmin = 11.75 and Qmax/Qmean = 2.10), Madeira (Qmax/Qmin = 7.34 and Qmax/Qmean = 1.85), and Negro (Qmax/Qmin = 4.68 and Qmax/Qmean = 1.92) exhibit greater variability and regime compared to the Congo and the Amazon (Figure 8).

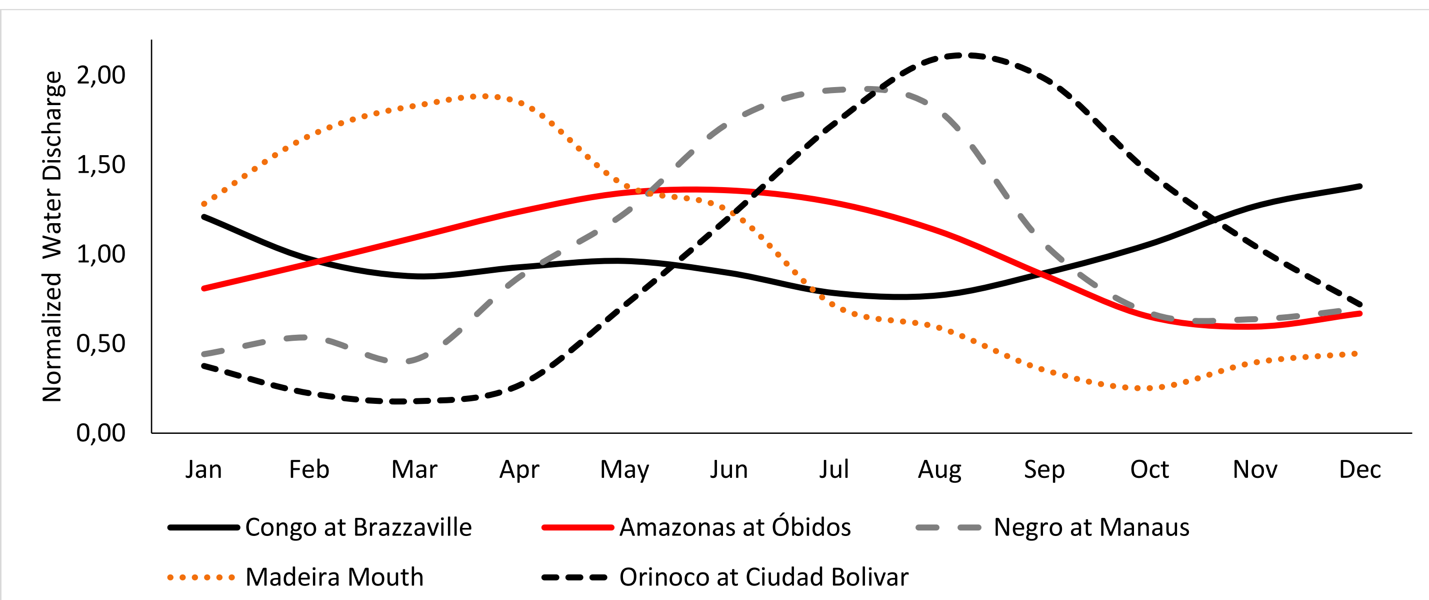

Figure 8 - Normalized Water Discharge for some of the World's largest rivers.
Source: Data from the Agência Nacional de Águas e Saneamento Básico and SO-HYBAM. This Work, 2024.

Several studies since the 1940s have analyzed the SSC of the Congo River (Table 1). SSC values in these studies range from 20 mg.L^{-1} (BISSEMO et al., 2023) to 32 mg.L^{-1} (STEVAUX; LATRUBESSE, 2017). The standard

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deviation is 3.44, and the coefficient of variation is 13.14%. The low variability between values indicates stability in SSC within the Congo River basin over the past 75 years.

Table 1 - Survey of different SSC, Qsa and Qsp data for the Congo River

SSC ($mg.L^{-1}$)	Qsa×10^6 ($ton.ano^{-1}$)	Qsp ($ton.km^{-2}.ano^{-1}$)	Date	Source
24.98	28.94	8.15	1993	Laraque et al. (2009)
-	43	-	1990	Meade (1996)
	32.8	9	-	Latrubesse et al. (2005)
32	48	-	-	Stevaux e Latrubesse (2017)
23.99 31.48	-	- 11.72	1987-1993 2000-2012	Datok et al. (2021)
-	32.8	9	-	Latrubesse (2008)
25.4	-	-	2006-2010	Laraque et al. (2013)
25.81	-	-	1987-1992	Laraque et al. (1993), Laraque e Olivry (1995)
-	47	13.16*	1948-1950	Devroey (1951)
-	31.2	8.9*	-	Gibbs (1967)
-	71.3	20.37*	-	Holleman (1968)
-	-	14.5	-	Holland (1978)
22.2-28.7	35-40	10-11.42	1978-1979	Molinier (1979)
-	40.56	11.35	-	Mouzeo (1986)
26.3	30.7	8.8	1990-1993	Coynel et al. (2005)
21.7	29.4**	8.41**	2009-2010	Spencer et al. (2016)
20-30	-	-	2013-2021	Bissemo et al. (2023)
27.2	-	-	2006-2017	Laraque et al. (2020)
27.2	33.76	9.62	2005-2018	This Work (2024)

*Calculations made considering the area drained by the Brazzaville station. **Calculations made according to Equations 2 and 3.
Source: This Work, 2024.

According to Laraque et al. (2009), 55% of the material transported by the Congo River originates from the upper reaches of the basin. The Kansai River, the main left-bank tributary, contributes 25% of the sediment production. The right-bank channels contribute 20%, with the Ubangi River accounting for 11% of this contribution. Much of the SSC transported by the Congo River basin is derived from erosion of the Congo Shield.

The hydrosedimentological characteristics of the Congo River differ from other tropical mega rivers such as the Madeira and Amazon rivers, which originate from the Andes Mountain range, and the Brahmaputra River, which originates from the Himalayan Mountain range. These rivers typically carry higher suspended sediment concentration due to the recent terrain in these mountain ranges. Conversely, rivers draining crystalline shields, such as the Congo (Congo Shield in Africa) and Negro (Guiana Shield in South America), transport low SSC due to the highly weathered nature of these areas. The Orinoco River in Venezuela, which drains areas of the Guiana Shield (older terrain) and part of the Andes Mountain range (recent terrain), has a higher SSC than rivers that drain exclusively crystalline shields like the Congo and Negro (Table 2).

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Table 2 - Hydrosedimentary characteristics of the world's main rivers

River	Drainage (10^3 km²)	Q ($m^3.s^{-1}$)	SSC ($mg.L^{-1}$)	Qsa×10^6 ($ton.ano^{-1}$)	Qsp ($ton.km^{-2}.ano^{-1}$)
Amazonas (South America)	6150	209 000 (a)	140	~1000	166.7
Congo(b) (Africa)	3500	41 268	27.2	33.76	9.62
Orinoco (South America)	990	33 910(b)	73.9(c)	74(c)	88.5(c)
Negro (d) (South America)	700	31 527(b)	5.28	5.76	8
Madeira (e) (South America)	1360	27 612(b)	25-622(f)	450	330.9
Brahmaputra (Asian)	610	20 000	1 719	520 (e)	852.4 (e)

(a) Molinier et al. (1996). (b) This Work (2024). (c) Laraque et al. (2013). (d) Marinho et al. (2022). (e) Latrubesse et al. (2005). (f) Villar et al. (2013).
Source: Adapted from Stevaux e Latrubesse, 2017; This Work (2024).

The Negro River basin has a denudation rate of 0.04 $mm.year^{-1}$ (WITTMANN et al., 2011), one of the lowest among the world's large rivers. In contrast, the denudation rate of the Congo River basin is estimated to be even lower at 0.00337 $mm.year^{-1}$. Rivers originating in the Andes exhibit significantly higher rates: the Amazon River at Óbidos (0.20 $mm.year^{-1}$) and the Madeira River near its mouth (0.21 $mm.year^{-1}$) (WITTMANN et al., 2011). However, differences in methods, basin area and the periods analyzed limit direct comparisons. According to Gaillardet et al. (1995), chemical denudation is intense in the Congo basin, but even when considering both chemical and mechanical silicate denudation, the values remain low (5 $mm.ky^{-1}$). This indicates that, among large tropical river basins, the Congo River basin currently has the lowest denudation rate.

The Congo River in Africa and the Negro River in the Amazon basin exhibit similar channel morphologies. Both rivers drain ancient terrains, carry a low load of suspended material dominated by bottom sediments, and feature intricate anabranching patterns (STEVAUX; LATRUBESSE, 2017). The correlation between suspended sediment concentration and precipitation is weak for both rivers, with coefficients of determination (R^2) of 0.22 for the Congo River and 0.16 for the Negro River, and moderate correlation coefficients (r) of 0.48 for the Congo River and -0.40 for the Negro River (Figures 9a, 9b). Notably, the relationship is negative for the Negro River. In contrast, rivers originating from the Andes exhibit a stronger correlation between SSC and precipitation (R^2 = 0.79, r = 0.89 for the Amazon and Madeira rivers), indicating a dependency on rainfall for suspended sediment transport (Figures 9c, 9d). This difference is likely due to the Congo and Negro rivers draining older, more weathered terrains.

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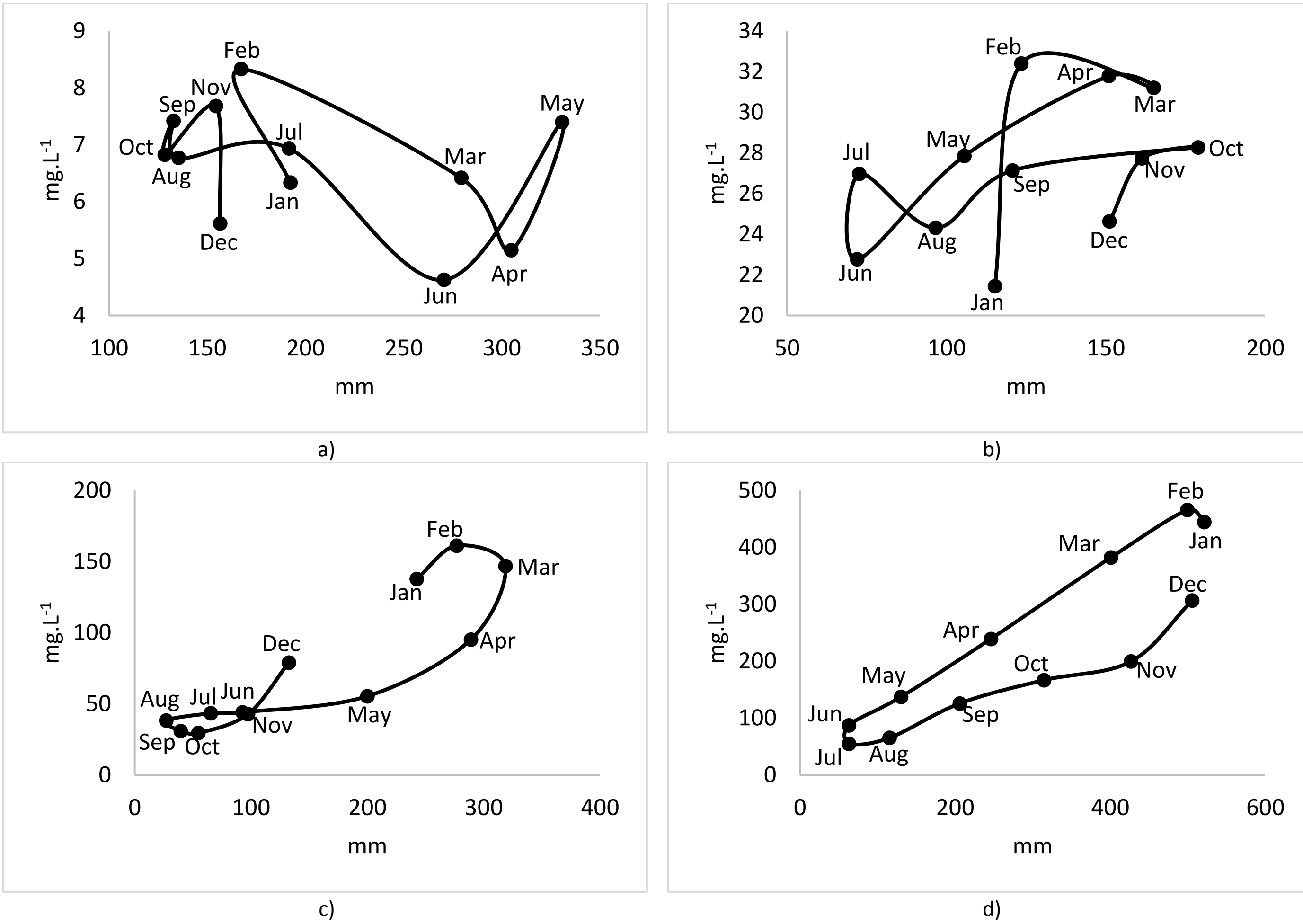

Figure 9 - SSC x Precipitation in mega rivers. a: Serrinha station (Negro River). b: Brazzaville station (Congo River). c: Óbidos station (Amazon River). d: Fazenda Vista Alegre station (Madeira River).
Source: Data from the Agência Nacional de Águas e Saneamento Básico, SO-HYBAM and Chirps. This Work, 2024.

Both the Congo and Negro rivers, characterized as mega complex anabranching channels, has extensive systems of stable archipelagos. The Negro River's notable archipelagos include the Anavilhanas Archipelago in the lower reach and the Mariuá Archipelago in the middle reach. The Anavilhanas Archipelago comprises over 400 islands, while the Mariuá Archipelago consists of more than 1 400 islands. These archipelagos exhibit a medium to high anabranching index, highlighting the intricate nature of the channel (MARINHO et al., 2021; QUEIROZ, 2022).

The island systems in the Congo River, although smaller, exhibit a high level of complexity, particularly in the middle reaches. O'Loughlin et al. (2013) analyzed the middle Congo River and found that each 10 km segment typically has fewer than 50 islands, with some sections having no islands at all. This contrasts with the Negro River, which contains over 1 400 islands in its middle reaches and features a valley that accommodates

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greater sediment deposition (QUEIROZ, 2022). However, the current suspended sediment concentration levels appear insufficient to form extensive archipelago systems, as noted by Marinho et al. (2020) for the Negro River.

Flugel et al. (2015) suggest that the current drainage characteristics of the Congo River basin developed between the end of the Neogene and the beginning of the Quaternary periods. During the Neogene, intensified deposition of terrigenous sediments in the coastal region likely resulted from Miocene uplift, which increased erosion, and was supported by climatic changes (LAVIER et al., 2001; SERANNE et al., 2008). Before establishing its current drainage pattern, the Congo River may have transported higher sediment loads, significantly influencing the stabilization of its drainage and channel morphology over time.

In the Congo River, climate change and land cover (vegetation) are the primary factors influencing the supply of water and sediment to the ocean. Over the past 185 000 years, water discharge has varied in response to climatic periods. During warmer stages (Marine Isotope Stages – MIS 1, 5a, 5c, 5e), mean discharge ranged between 40 000 $m^3.s^{-1}$ and 50 000 $m^3.s^{-1}$, whereas during colder stages (MIS 2, 4, 6), mean discharge was approximately 35 000 $m^3.s^{-1}$ (MOLLIEX et al., 2019).

Molliex et al. (2019) identified a negative correlation between water discharge and sediment supply over the past 185 000 years, spanning the Quaternary period, supporting the current low correlation observed. Their findings indicate that sediment supply in the Congo River basin is more responsive to changes in vegetation cover than to climate change, with variations of up to 30% between post-glacial phases and present-day conditions. The recent increase in deforestation within the Congo basin is likely to have a direct impact on sediment production transported to the ocean. Between 1990-2000 and 2000-2005, deforestation rates in the Congo River basin doubled from 240 000 $ha.year^{-1}$ to 480 000 $ha.year^{-1}$. Although the annual loss of vegetation cover in the Congo River basin is lower compared to other tropical forest regions, the trend in annual deforestation rates is increasing (ERNST et al., 2013).

V. Final Considerations

The Congo River, the second largest river globally by water volume, has a mean annual water discharge of approximately 41 268 $m^3.s^{-1}$. Its seasonal amplitude ranges from 25 132 $m^3.s^{-1}$ during low water periods to 56 959 $m^3.s^{-1}$ during peak flow months in December. This river plays a crucial role in transporting water to the Atlantic Ocean, exhibiting a relatively regular discharge regime with low variation between maximum and minimum annual discharges, as well as a consistent flood regime.

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The annual suspended sediment concentration (SSC) for the Congo River is 27.20 $mg.L^{-1}$, which is considered low compared to other mega rivers. This low SSC is attributed to the basin draining older and highly weathered land, similar to the Negro River in South America. Consequently, the current denudation rate is one of the lowest in the world (0.00337 $mm.year^{-1}$).

In the Congo basin, there is a moderate direct relationship between precipitation and SSC, as well as a weak relationship between water level and SSC. These relationships are possibly influenced by the characteristics of the basin's drainage area. Annually, the Congo River transports approximately 33.66×10^6 tons of sediment to the Atlantic Ocean, with a specific sediment yield of 9.62 $ton.km^{-2}.year^{-1}$. SSC data observed since the 1940s indicate minimal variation over the last 75 years, suggesting a stable regime for this mega river system. However, recent increases in deforestation within the basin may potentially alter the SSC dynamics.

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