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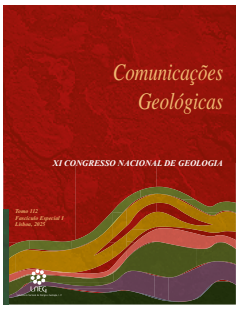
Environmental changes in the Atlantic World: how did the trade of enslaved people shape the landscapes.

Transformações ambientais no Mundo Atlântico: como é que o tráfico de pessoas escravizadas transformou as paisagens.



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Abstract: This paper focuses on the environmental changes that occurred along the margins of Cacheu River (Guinea-Bissau) and Sado River (Portugal), in the context of the transatlantic trade of enslaved people and its aftermath (15th century to the present). We collected four sediment cores in the estuarine areas of those two rivers – Cacheu1, Cacheu2, Cacheu3 and Laxique. The sediments were analysed for environmental proxies and radiocarbon dated. The preliminary analyses of Cacheu1 and Cacheu2 reveal a long sedimentary sequence covering changes over the last 8000 years. The preliminary analyses of sediments collected from the Sado River indicate anthropic influence and the introduction of N-fertilisers in the river alluvial plain before the 18th century, probably related to the production of rice. New dating will improve the resolution of the age-depth models produced for the sedimentary sequences in recent years and will allow a more accurate environmental evolution model.

Keywords: paleoenvironmental reconstruction, Cacheu River, Guiné-Bissau, Sado River, Portugal

Resumo: Este artigo foca-se nas mudanças ambientais que ocorreram ao longo das margens do rio Cacheu, na Guiné-Bissau, e do rio Sado, em Portugal, no contexto do comércio transatlântico de pessoas escravizadas e suas consequências (do século XV até o presente). Foram recolhidas quatro sondagens de sedimentos nas áreas estuarinas de ambos os rios - Cacheu1, Cacheu2, Cacheu3 e Laxique. Os sedimentos foram analisados para diversos indicadores ambientais e datados por radiocarbono. As análises preliminares de Cacheu1 e Cacheu2 revelam uma sequência sedimentar longa cobrindo as mudanças ambientais dos últimos 8000 anos. As análises preliminares dos sedimentos de Laxique1 indicam influência antrópica e a introdução de N-fertilizantes na planície aluvial do rio antes do século XVIII, provavelmente relacionados com a produção de arroz. A realização de novas datações permitirá melhorar a resolução dos modelos de idade para anos mais recentes e permitirão a elaboração de um modelo de evolução ambiental mais fidedigno.

Palavras-chave: reconstrução ambiental, Rio Cacheu, Guiné-Bissau, Rio Sado, Portugal

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1. Introduction

Between the 15th and 20th centuries, more than 12 million people were enslaved, forced to leave their lands, and sent to various destinations in the Americas and Europe (www.slavevoyages.org). The environments and landscapes of origin and destination of these millions of displaced people would have undergone changes, as the environmental conditions of each society are largely defined by the interactions between the population, animals, plants, and the surrounding landscape. According to estimates provided in the SlaveVoyages database (www.slavevoyages.org, consulted in January 2023), about 755,000 people were forced to embark from Senegambia (a geographical area of West Africa roughly comprising Senegal and Sierra Leone, including Guinea-Bissau) and neighboring areas, with approximately 6,000 of them being taken to Europe between 1601-1800. Many of them would have disembarked and stayed in Portugal. Although the total number of people forced to work along the estuaries of the Tagus and Sado rivers is unknown (Carmo *et al*., 2020, and references therein), the presence of enslaved people in agriculture and other activities developed in the estuarine areas of the Tagus and Sado rivers is documented, especially regarding salt extraction (Saunders, 1982; Henriques, 2021). Some research proposals hypothesized that rice cultivation on the banks of these estuaries could have been carried out by enslaved people during the 15th to 18th centuries (Carmo *et al*., 2020). There is a growing interest for this topic among academics and local communities.

Based on two study areas - the Cacheu River in Guinea-Bissau and the Sado River in Portugal - which played opposing roles in the enslavement process, the objectives of this work are: i) to characterize the environmental context and its evolution in the valleys of the Cacheu River and the Sado River over, at least, the last 1000 years; ii) to identify land use changes on the banks of the Cacheu River (from where thousands of people were forced to embark) and the Sado River (where an unknown number of people were forced to work, or where individuals of African descent settled after the abolition of slavery); and iii) to contribute to the understanding of the environmental changes produced in different geographical areas by societies heavily influenced by the institution of slavery, before and after formal abolition.

Although this work is focused on the last six centuries, to our best knowledge the environmental history during the Holocene of Guinea-Bissau is still lacking in information, and a first attempt of

characterizing the landscape evolution from this area will be performed, taking advantage of the obtained sedimentary records. Only by knowing the natural environmental conditions and its changes through the Holocene in response to climate change and sea-level rise it will be possible to understand the changes derived from anthropogenic actions.

2. Study areas settings

Cacheu is located on the NE of Guinea-Bissau, West-Africa, close to the Senegal border. The city develops around the left side of River Cacheu estuary, one of the largest rivers from Guinea-Bissau. The estuarine margins are colonized by extensive mangroves, being one of the most continuous mangroves of this type in West Africa, with this habitat (*Rhizophora* sp. and *Avicenia* sp.) occupying 50% of the area. The mangroves are protected under the Ramsar convention, and a Natural Park was created in 2000 (Parque Natural dos Tarrafes do Rio Cacheu).

The local Mean Sea Level (MSL) locates at 1.6 m above HZ (Fandé *et al*., 2022). The estuary has semi-diurnal tides, with a maximum tidal range of 2.76 m (https://www.hidrografico.pt/, consulted in July 2023).

The local geology, covering the Miocene and Pliocene, is characterized by detritic sediments composed by sand and clay, as a result of the estuarine-deltaic activity (Alves and Carvalho, 2011). Some of these deposits have been used for agriculture practices. Additionally, we can find beach sand deposits, with more or less clay, colonized and stabilized by the mangroves, particularly in the right margin of the estuary (Alves and Carvalho, 2011).

The Sado river is located in southwest Portugal. It is one of the largest Portuguese rivers, with a maximum length of ca. 175 km and draining a wide watershed area with ca. 7700 km^2 (INE, 2007). The terminal stretch corresponds to a bar-built estuary with a mean depth of ca. 8 m, reaching 44 m in the main channel near the inlet (Brito, 2009). The estuary is protected by the Tróia sand spit that started to growth northwards ca. 6500 cal BP (Costas *et al*., 2015) and it reaches the Atlantic Ocean through a narrow inlet (ca. 2 km) located between Tróia and Setúbal. The estuary extends for 50 km considering the maximum salt-water intrusion or 57 km if the upper limit of dynamic tide is considered (Bettencourt and Ramos, 2003). It is a well-mixed mesotidal estuary (*e.g.* Martins *et al*., 2000; Biguino *et al*., 2021), with estuarine semi-diurnal tides, the tidal range varying between 1.5 m and 3.9 m during neap and spring tides, respectively (Bettencourt and Ramos, 2003).

The lower Sado river is embedded in Pre-Quaternary formations, and at Laxique it crosses the Paleogene formation of Vale do Guizo, composed of alluvial pinkish sandy conglomerates and marly clays (Antunes *et al*., 1983; Gonçalves and Antunes, 1992; Pimentel, 2002).

3. Materials and Methods

From Cacheu, three cores (Table 1) were retrieved in March 2022 along

Table 1. Location and elevation of ground surface at core location for the cores studied in this work. Coordinates are provided in WGS84 coordinate system. Elevations are given relatively to mean sea level (MSL).

Tabela 1. Localização e cota da superfície do solo no local da sondagem para as sondagens estudados neste trabalho. As coordenadas são fornecidas no sistema de coordenadas WGS84. As cotas são fornecidas relativamente ao nível médio do mar (MSL).

Core reference	Easting	Northing	Elevation of ground surface at core location (m MSL)	Collected core length (cm)	First published in
Cacheu1	-16.162913	12.278598	0.5	428	Arvela *et al.*, 2023
Cacheu2	-16.157462	12.278250	0.6	390	Arvela *et al.*, 2023
Cacheu3	-16.138056	12.270278	0.8	356	Arvela *et al.*, 2023
Laxique	-8.252777	-8.375432	6.1	810	Costa *et al.*, 2022

Table 2. Radiocarbon determinations in organic sediment for the cores Cacheu1, Cacheu2 and Laxique. The dates have been calibrated with the IntCal20 curve (Reimer *et al.*, 2020) using the Oxcal v.4.4 (© Bronk Ramsey, 2020) and the NH zone 2 curve (Hua *et al.*, 2013)*. UOC - reference for samples analysed at A.E. Lalonde AMS Laboratory and Beta - reference for samples analysed at Beta Analytic Laboratory.

Table 2. Determinações de radiocarbono em sedimentos orgânicos para os testemunhos Cacheu1, Cacheu2 e Laxique. As datas foram calibradas com a curva IntCal20 (Reimer et al., 2020) usando o Oxcal v.4.4 (© Bronk Ramsey et al., 2020) e a curva NH zona 2 (Hua et al., 2013)*.

Sample reference	Lab code	Material	Core depth (cm)	Height (cm MSL)	δ13C (‰)	Conventional ^{14}C age BP	Calibrated age BP (95%)	Reference
Cacheu1#12 354-356	UOC-22469	Bulk organic sediment	355	305	-	7399±25	8329-8171 (92.9%) 8074-8055 (2.5%)	This work
Cacheu2#12 386-388	UOC-22468	Bulk organic sediment	387	327	-	7535±22	8401-8326 (92.6%) 8236-8223 (2.8%)	This work
Laxique1 150-152*	Beta-510626	Bulk organic sediment	151	459	-24.9	101±0.38pMC*	-6 to -7	Costa *et al.*, 2022
Laxique 320-322	Beta-482231	Bulk organic sediment	321	289	-25.8	1060±30	1056-1024 (16.8%) 1007-926 (78.6%)	Costa *et al.*, 2022
Laxique1 521-523	Beta-51062	Bulk organic sediment	522	88	-26.0	3670±30	4090-3900 (95.4%)	Costa *et al.*, 2022
Laxique 801-803	Beta-476962	Bulk organic sediment	802	-191	-25.9	3940±30	4515-4480 (10.2%) 4445-4289 (82.8%) 4270-4254 (2.5%)	Costa *et al.*, 2022

the left estuarine margin using a *van der Horst* corer. The location of the sediment cores was defined based on proximity/distancing of the Cacheu urban center, the presence/absence of mangrove and the presence/absence of rice fields. Cores have a total length between 3.5 and 4.3 m. For a practical handling of the samples, the cores were sub-sampled each 2 cm in Cacheu for further transport and analysis.

Laxique was collected in 2017 at the Sado alluvial plain, 65 km upstream the present-day estuary inlet and near a property where slavery-based work is known to have occurred (*e.g.* Henriques, 2021). The sediment core was collected using a coring device Cobra TT of Atlas Copco and a hydraulic lifting unit using closed PVC tubes.

Samples have been analysed for sedimentology (texture, organic matter and $CaCO_3$ contents, and magnetic susceptibility) and also for organic chemistry (only in Laxique core), using standard procedures described in Costa *et al*. (2022) and Arvela *et al*. (2023). Until the moment, 2 samples from Cacheu and 4 samples for Laxique (Table 2) were radiocarbon dated. Radiocarbon dates yielded at the base of Cacheu1 and Cacheu2 allowed to constrain the bottom of the two sedimentary columns at ca. 8400 to 8200 cal BP (Figura 1; Table 2) respectively. The 4 dating performed at Laxique allowed to draw an age-depth model covering the last 4500 years (Costa *et al*., 2022). However, more radiocarbon dates are needed to achieve accurate chronologies and built accurate age-models, particularly for the time-period considered in this work.

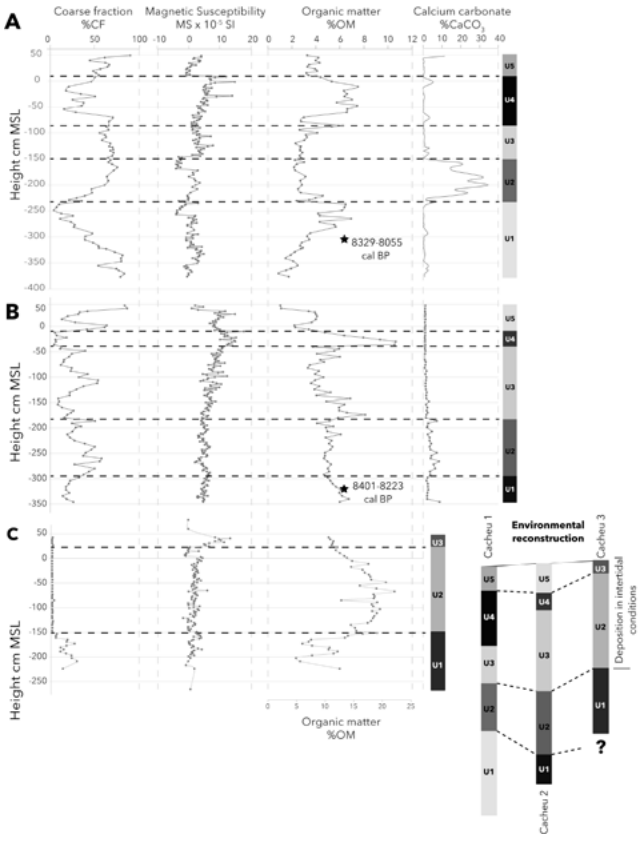

Figure 1. Representation of the sedimentological proxies against height (m MSL): coarse fraction (CF), magnetic susceptubility (MS), total organic matter (OM) and calcium carbonate ($CaCO_3$) for Cacheu1 (A), Cacheu2 (B) and Cacheu3 (C) and preliminary environmental reconstitution.

Figura 1. Representação dos indicadores sedimentológicos em relação à cota (m MSL): fração grosseira (CF), suscetibilidade magnética (MS), matéria orgânica total (OM) e carbonato de cálcio ($CaCO_3$) para Cacheu1 (A), Cacheu2 (B) e Cacheu3 (C) e reconstituição ambiental preliminar.

4. Results and Discussion

Cacheu, Guinea-Bissau

Due to major changes in the proxies profiles of texture, magnetic susceptibility (MS), organic matter (OM) and calcium carbonate ($CaCO_3$) contents in depth, 5 main sedimentary units were defined in Cacheu1 and Cacheu2 (Figura 1A and B), and 3 sedimentary units were considered in Cacheu3 (Figura 1C).

The dates obtained for the samples collected from Cacheu1 and Cacheu2 yielded values in the intervals 8329-8055 cal BP and 8401-8223 cal BP, respectively (Figura 1; Table 2), representing the Northgrippian and Meghalayan ages (Mid and Late Holocene).

Cacheu1 Unit 1 (U1), at the base of the sedimentary sequence, shows a progressive decrease in the coarse fraction and a progressive increase in the OM content, pointing to a decrease in the hydrodynamic conditions of the area. MS and $CaCO_3$ values are low. Unit 2 (U2) is rich in gastropods and bivalve whole shells with diferent dimensions and, consequently, presents high $CaCO_3$ contents of ca. 35% and a higher coarse fraction percentage (Figura 1A). The environmental conditions in U2 that led to the accumulation of molusks probably due to higher marine influence derived from lower river flow and less sediment influx. In Unit 3 (U3), MS, OM and $CaCO_3$ contents are similar to U1, pointing to similar conditions but in a slightly higher energy environment (the sand fraction increase). According to its relation to present-day MSL, U3 was deposited in the transition to an intertidal environment.

In Unit 4 (U4) the coarse fraction decreases significantly and the OM increases, probably in response to a decrease in the hydrodynamic conditions. According to our preliminary interpretations sedimentation occurred in a low intertidal environment, forming a tidal flat. Unit 5 (U5), at the top of the sedimentary sequence, was deposited in a high intertidal environment. It is constituted by muddy sand with some pebbles at the top. Several coloured spots were identified during sampling, that are probably related with anthropic activities in the margin or accumulation of waste.

In Cacheu2, U1, at the base, is composed by sandy mud with low response to MS and low contents in $CaCO_3$. In U2, the coarse fraction percentage increases as well as the $CaCO_3$ content, in response to the presence of shell and shell fragments, reflecting a change in the environmental conditions similar to Cacheu1. The observation of samples under the microscope, reveal in this unit the presence of silicious sponge spicules and whole and fragmented diatoms frustules. In U3, constituted by alternations of sandy mud and muddy sand, the MS values increase progressively to the top, while organic matter seem to decrease. The $CaCO_3$ content decreases to values near 0%. U4, near the present-day MSL, is constituted by mud with high content of OM and the highest values of MS of the entire core (as in U4 of Cacheu1). U5, at the top, is coarser, the OM content decreases and MS values slightly decrease in relation to U4. The very top of the unit is composed by sand, with values of MS, organic matter and $CaCO_3$ of ca. 0. The observation of samples under the microscope of Units 3 to 5, reveal the presence of rare silicious sponge spicules and rare fragmented diatoms frustules.

In Cacheu3, the $CaCO_3$ of the entire core is very low (near 0). In U1, at the base, the sediment is constituted by slightly sandy mud, with MS values between -1 and $4x10^{-5}$ SI. The OM content varies between 5 and 20%. In U2, constituted by mud, the organic content is very high (similarly to Units 4 of Cacheu1 and Cacheu2), with values usually higher than 15%. In U3, at the top, the organic matter decreases progressively to the top while MS values increase reaching a maximum value of $12x10^{-5}$ SI. Despite the environmental modifications identified in the margins of the Cacheu estuary, landscape and land-use changes of the estuarine marginal area can only be ascertained

after the conclusion of the on-going palynological, paleobotanical and sedimentary DNA studies.

Sado, Portugal

Due to major changes in the proxies profiles, 6 main sedimentary units were defined in Laxique. According to the age model produced (Costa *et al*., 2022), Unit 6, corresponding to the top 3 meters of the sedimentary sequence, was deposited during the last 1000 years, covering the time period of interest for this work (described below). The complete dataset can be found in Costa *et al*. (2002).

Unit 6 was defined between 289 and 610 cm MSL, and is essencially composed by a slightly sandy mud (coarse fraction between 10 and 20%) with OM values between 3 and 7%. Particularly, the increase of $\delta^{13}C$ to values higher than -25‰, of N to maximum values of 0.18% and of $\delta^{15}N$ to values higher than 6‰ in this unit, that corresponds to the aggradation of the alluvial plain and with no influence of marine water, point to the adding of N-fertilisers, such as manure, to the soils since, at least, ca. 700 cal BP (Costa *et al*., 2022; Figura 2). In addition, MS and the sand content increase in relation to the units below, pointing to high fluvial activity, and possibly to wetter conditions that can also contribute to higher $\delta^{13}C$ values in the bulk organic sediment (Costa *et al*., 2022).

The Laxique sediment core was collected near the Herdade de Laxique, where the presence of enslaved people working in agriculture was already described (*e.g.* Carmo *et al*., 2020; Henriques, 2021). Could the environmental changes identified in Laxique and described above be the result of this labor?

5. Final considerations

Based on the sedimentary record, this research aims to characterize the environmental/landscape changes occurred in the last centuries in Guinea-Bissau and Portugal, and the potential role of slavery in those transformations. Could the development of agricultural practices, including rice production, in the margins of both the Cacheu and the Sado estuaries have led to environmental/landscape changes? While paleoecological proxies are still being analyzed in the cores collected at Cacheu (Guinea-Bissau), the preliminary results achieved from the multyproxy analyses performed in the Sado (Portugal) point to changes in the environmental conditions and landscape, at least, during the last 700 years. The sediment record might contain information concerning the presence of enslaved individuals who worked the alluvial plains of the Sado river.

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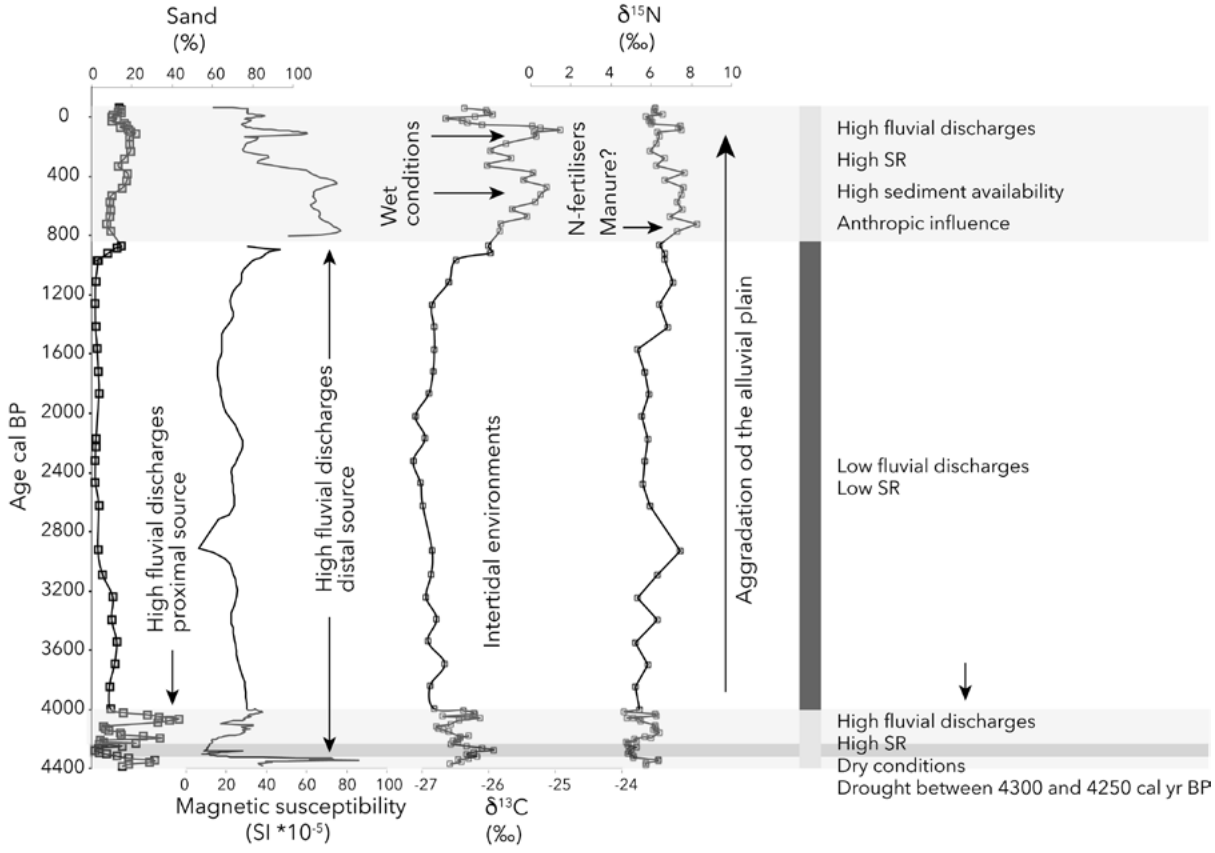

Figure 2. Representation of the sedimentological proxies against height (m MSL): coarse fraction (Sand), magnetic susceptibility (MS), $\delta^{13}C$ and $\delta^{15}N$ for Laxique and summary of environmental changes through time (adapted from Costa *et al.*, 2022).

Figura 2. Representação dos indicadores sedimentológicos em relação à cota (m MSL): fração grosseira (sand), susceptibilidade magnética (MS), $\delta^{13}C$ e $\delta^{15}N$ para Laxique e síntese das variações ambientais através do tempo (adaptado de Costa et al., 2022).

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